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GEOLOGICAL MAGAZINE

VOL. LXXXVI. No. 6. NOVEMBER–DECEMBER, 1949

The Ammonite Genus *Uhligella* in the English Albian[1]

By R. CASEY

(PLATE XIX)

ABSTRACT

Uhligella is one of the links between the Hoplitidae and their smooth Desmoceratid ancestors, and occurs typically in the Albian of the Mediterranean Province. Two new species of *Uhligella* found in the Middle Albian of Folkestone provide the first record of the genus in England. Description of the Folkestone specimens is preceded by a discussion of the genus, its circumscription, taxonomy, and systematic position.

I. INTRODUCTION

THE following pages give an account of two new species of ammonoidea from the Lower Gault and Mammillatum bed (Middle Albian) of Folkestone, both referable to *Uhligella* Jacob. This genus is of considerable interest as providing one of the few known links between the smooth or feebly ornamented Desmoceratidae,[2] dominant in the Mediterranean Province, and their highly modified offshoots, the Hoplitids, so familiar to the student and collector of Gault fossils in this country. In the scheme of phylogeny of the Hoplitidae put forward by Spath (1942, p. 687) *Uhligella* (in a wide sense) is represented as a persistent stock from which diverged successive Hoplitid branches during Lower and Middle Albian time. Like *Desmoceras* itself and the various developments of the fundamental Phylloceratidae and Lytoceratidae, *Uhligella* also characterizes the Albian deposits of Mediterranean regions (Jacob, 1907, p. 391), and judging by present knowledge of its distribution it rarely penetrated to those northerly waters in which were dispersed its more specialized allies. There is no previous record of the genus in England. It appears, however, that one of the species of *Uhligella* described in the present paper was known already to the early investigators of the Folkestone Gault, De Rance (1868) and Price (1874), who seem to have regarded it as a form of *Ammonites deshayesii* (Leymerie MS.) d'Orbigny, an

[1] Published by permission of the Director, Geological Survey and Museum.

[2] Desmoceratidae and Hoplitidae are here used in the familiar sense, complying with the usage of L. F. Spath in his "Monograph of the Ammonoidea of the Gault" (1923–1943). If one accepts the opinion of M. Breistroffer (1947, pp. 59, 83–4) both these family designations must be rejected as invalid according to the International Rules of Zoological Nomenclature.

Aptian species which has since been made the type of the genus *Deshayesites* (Parahoplitidae).

Since *Uhligella* is probably not very well known to the majority of geologists and collectors in this country and has a confused taxonomic record, the paper includes a brief review of the genus.

My thanks are due to Dr. C. J. Stubblefield and Mr. R. V. Melville for allowing me to make use of the collections in their charge at the Geological Survey Museum, where the material formerly in my possession is now deposited. Similar facilities were afforded me at the British Museum (Natural History) by Mr. W. N. Edwards and Dr. L. F. Spath, and at the Sedgwick Museum by Mr. A. G. Brighton. Specimens in the various institutions are indicated in the text by their appropriate registration numbers preceded by the symbol G.S.M. (Geological Survey Museum), B.M. (British Museum), or S.M. (Sedgwick Museum).

II. Systematic Account

Family *DESMOCERATIDAE*

Genus **Uhligella** Jacob, 1907, emend. Breistroffer, 1947

Genolectotype (selected Kilian, 1907, p. 63).—*Desmoceras clansayense* Jacob ; Lower Albian, " Clansayes " horizon (*nodosocostatum* zone). Drôme, S.-E. France (see Jacob, 1905, pp. 403–4).

Uhligella comprises moderately involute, discoidal shells with arched venter and compressed, elliptical whorl-section. Intermittent shallow constrictions are characteristic. The early volutions are costate and are more or less tuberculated around the umbilicus ; with subsequent growth the sculpture gradually fades until the shell attains or approaches the laevigate condition. There is a good deal of variation in the strength and duration of the sculptured stage. In *U. rebouli* (Jacob), for example, the costae are relatively subdued and only the insignificant bullae at their umbilical ends distinguish this form from certain feebly ribbed developments of the Desmoceratid *Beudanticeras*. At the other extreme *U. balmensis* (Jacob) [1] has boldly ribbed and

[1] Concerning this species, Spath (1925, p. 93) writes : " [it] . . . might with propriety be included in *Sonneratia*, although its suture-line is still in the ' *Desmoceras* ' stage." Elsewhere in the same work (pp. 35, 63, 95, 693) it is referred sometimes to *Sonneratia*, sometimes to *Cleoniceras*, either with or without a mark of interrogation. In retaining the species in *Uhligella* I am influenced not so much by the fact that it is connected by a graduated series of passage-forms to *U. rebouli* (Jacob), and thence to *Beudanticeras walleranti* (Jacob), as by its constrictions, suture-line, and Desmoceratid outer whorls. (Compare *U. besairiei* Breistroffer sp., 1936, pl. xv, figs. 17–18, p. 156.) The Californian ammonites included in the group of *Uhligella balmensis* (Jacob) by Anderson (1938, p. 193) belong to a distinct genus for which the name *Coloboceras* Crickmay is available and should be used.

tuberculated inner whorls that are but a step removed from a *Sonneratia* or a *Cleoniceras*, both classified among the early Hoplitidae. Sutural characters are of limited diagnostic value in this group. Generally speaking, the suture-line of *Uhligella* is less simplified than that of *Sonneratia* or *Cleoniceras*, but as in other stocks which show the change from the liostracous to the trachyostracous state, individual species display great variability in the extent to which the septal suture is affected in the process of transformation. Previous authors have pointed out that the degree of symmetry of the principal lobe does not provide a satisfactory means of separating *Uhligella* from *Desmoceras*, as held by Pervinquière (1907, p. 129). Similarly, the disparity in the development of the internal and external portions of the second lateral saddle and certain ontogenetic changes in the relative length of the ventral and first lateral lobes, said by Chaput (1920, pp. 182–3) to characterize *Uhligella*, are not likely to afford much assistance in generic discrimination, since these features are apt to appear in ammonites of similar whorl-shape irrespective of phyletic relationship.

It is improbable that the genus embraces a natural group of species : almost certainly it includes forms that are linked independently to *Beudanticeras*, which according to the belief of Spath (1923, p. 37) cannot be far removed from the stable Phylloceratid root-stock. There are facts, however, which tend to favour the alternative view that *Beudanticeras* is composed, in part at least, of *Uhligellae* which forsook the Hoplitid trend at an early stage in their evolution and reverted to smoothness. Whatever its phylogenetic significance, the approximation of *Uhligella* to *Beudanticeras* on the one hand and to *Sonneratia* and *Cleoniceras* on the other, has always made it difficult to set bounds to the genus and authors have differed widely in their interpretation. Furthermore, there has been a tendency to misapply the name in the literature of the past forty years owing to misconceptions as regards the genotype. When introducing *Uhligella* (as a subgenus of *Desmoceras*) Jacob did not indicate a type-species, the name being applied to three " types principaux ", *D. seguenzae* (Coquand) Sayn sp., *D. zurcheri* Jacob, and *D. clansayense* Jacob, and to a number of *nomina nuda*, *D.* (*U.*) *walleranti*, *D.* (*U.*) *rebouli*, etc. (Jacob, 1907, p. 350). The first citation of a type for *Uhligella* was made by Kilian (1907, p. 63) in the same year, fixing *D. clansayense* Jacob as the type. Jacob's own designation of *D.* (*U.*) *walleranti* as the type of *Uhligella*, although widely quoted by subsequent authors, was not published until the year following (Jacob, 1908, p. 26) and, in any case, is open to objection, since *D.* (*U.*) *walleranti* was not one of the three principal species on which he founded the subgenus. Moreover, it is now agreed that *D.* (" *U.*") *walleranti* Jacob is congeneric with *Ammonites*

beudanti Brongniart, the genotype species of *Beudanticeras* Hitzel. R. Douvillé (1911, p. 218) incorrectly cited *D. seguenzae* (Coquand) Sayn sp. as the type of *Uhligella*, and the same error is made by Roman in his Ammonite Synopsis (Roman, 1938, p. 404). Spath, on the other hand, states that he has used *Uhligella* [*sensu stricto*] for the *zurcheri* group only (Spath, 1942, p. 686).

In the present paper *Uhligella* is adopted with the circumscription given it by Breistroffer (1947, pp. 63–4). Future study will probably show that the pre-Albian forms of the type of *U. seguenzae* and *U. zurcheri*, in which the ribs make no feature at the umbilicus, must be accommodated elsewhere, for they are not strictly congeneric with *D. clansayense* Jacob. The Mexican species " *U.*" *aguilerae* and " *U.*" *jacobi*, described by Burckhardt (1925, pp. 10–12, plate ii, figs. 4–10) represent yet another of these ribbed developments of the Desmoceratidae and the group should be given taxonomic recognition by a reviser who has access to actual specimens.

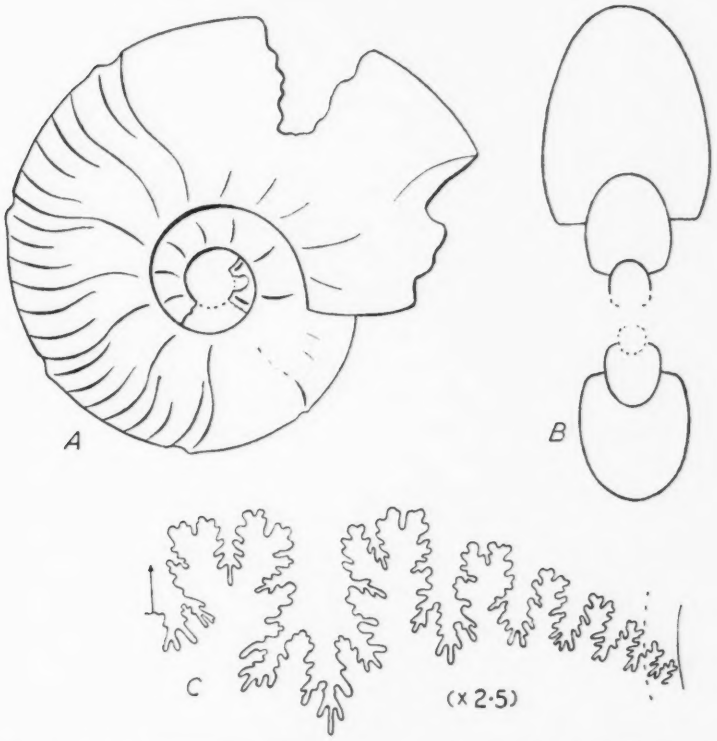
The systematic standing of *Uhligella*, *Lemuroceras*, and other genera which lie on the border-line of the Desmoceratidae and the Hoplitidae, is unsatisfactory, the family assignment being largely a matter of personal approach. The position with regard to *Uhligella* was discussed briefly by H. Douvillé (1916, pp. 370–1), who suggested that on account of its almost obsolete constrictions, tuberculation, and style of ribbing, the genus should be transferred from the Desmoceratidae to the Hoplitidae. Yet in this genus features of Hoplitid affinity are transitory, confined to the early stages of growth, and never become established in the adult, the outer whorls quickly returning to the ancestral, unspecialized condition. The ontogeny of *Uhligella* does, in fact, add to the body of evidence which has accumulated in recent years (mainly through the work of Spath) to show that evolution in the Ammonoidae often proceeded along proterogenetic (coenogenetic) lines ; but the application of this principle to matters of classification has yet to be investigated. In the circumstances it would be considered appropriate, perhaps, to take advantage of the family unit " Cleoniceratidae ", created by Whitehouse (1926, p. 206) for *Cleoniceras*, *Sonneratia*, and other ribbed Desmoceratid offshoots which precede the typical, ventrally sulcate Hoplitidae, and which might be extended to embrace *Uhligella*. Reasons for not adopting this " family " will be stated fully elsewhere : it must suffice for the present to remark that research into the origin and inter-relationships of the early Albian Hoplitidae, facilitated by undescribed material from the English Lower Albian, has made it clear that attempts to detach " Cleoniceratidae " from the main body of the Hoplitidae would increase rather than remove the systematic difficulties. For convenience *Uhligella* is here retained in the family Desmoceratidae.

Uhligella subornata sp. nov.

Plate XIX, figs. 1*a–b* ; Text-fig. 1

Material.—One specimen, G.S.M. 70442 (R. Casey Collection).

Horizon and Locality.—Top of Folkestone Beds (Mammillatum bed). Middle Albian, *mammillatum* zone, *monile* subzone. Foreshore reefs just east of Copt Point, Folkestone.



TEXT-FIG. 1.—*Uhligella subornata* sp. nov. Holotype (R. Casey Collection, G.S.M. 70442). Side view (*A*) and cross-section (*B*) ; with external suture-line (*C*) enlarged × 2·5. Middle Albian, Mammillatum bed (*monile* subzone), Copt Point, Folkestone.

Description of Holotype.—The unique example on which this species is based has the following dimensions :—

Diameter in mm.	65
Whorl-height (in % of diameter) . .	45
Whorl-thickness (in % of diameter) . .	35
Umbilicus (in % of diameter) . . .	28

The specimen is an internal mould in black phosphorite, abraded on the side not figured, wholly septate, and with part of the nucleus missing. A scar may be traced along the line of involution for another three-quarters of a whorl, indicating that with the body-chamber the ammonite was at least twice its present size.

The whorls are compressed, progressively increasing in relative height. At a diameter of 40 mm. the cross-section shows the greatest whorl-thickness a little below mid-height and the flattened sides bowed gently outwards in continuity with the curve described by the broadly rounded venter. In the course of growth the point of maximum thickness moves dorsally, the sides become more convergent, the venter in consequence decreases in relative width. At 20 mm. the smooth umbilical wall is high and fairly well turned, though not marked off distinctly from the flanks ; it becomes steeper as growth proceeds, maintaining a rounded border up to about 60 mm. diameter ; thence it becomes perpendicular and angular at the rim.

Costation consists of primary ribs, feebly bullate at the umbilical border in the young, with one to three, generally three, shorter secondaries between the primaries. The irregular union of one or two secondaries with a primary rib is indistinct, since the ammonite tends to smoothness just below the middle of the sides. The primary ribs number twelve to a volution at 40 mm. diameter, but are rather more closely set on the final, degenerate, half-whorl.

Regularly spaced constrictions, about eight per whorl, are confined to the outer zone of the sides and the venter. These constrictions, which are rather strongly marked for the genus, lie between a primary and a secondary rib. The rib preceding the constriction is thickened into a labial ridge and makes a positive feature on the peripheral outline. Otherwise, the ribs are in low relief and, after losing the umbilical bullae, are most pronounced on the ventro-lateral slopes. Ribs and constrictions traverse the flanks in a sigmoidal curve, of which the shortest secondaries complete only the upper flexure, and pass over the venter with a slight forward bend. On the innermost whorls (as revealed in the dorsal area) the ornamentation of the venter is more strongly projected forward. Degeneration of the sculpture sets in apparently from about 20–25 mm. diameter ; at a diameter of 55 mm. the ribs are fading rapidly and at 65 mm. have almost disappeared.

The suture-line has a deep, trifid, asymmetrical principal lobe and markedly dependent auxiliaries.

Remarks.—Uhligella subornata has a close analogue in *U. rebouli* (Jacob), which ranges from the *tardefurcata* to *dentatus* zones in the south-east of France (Jacob, 1908, pp. 32–4, plate xiv (iv), figs. 1–2). That species may be distinguished from *U. subornata* chiefly by its

relatively slender whorls, fainter constrictions, greater involution, and more highly dissected suture-line. Specimens from the Balearic Islands attributed to *U. rebouli* by P. Fallot (1910, p. 78, plate ii, figs. 1–2) agree more closely with the present species in dimensional proportions but have a narrower venter and more numerous and more sinuous primary ribs, in addition to a smoother nucleus.

Uhligella balmensis (Jacob), an associate of *U. rebouli*, has much too robustly ornamented inner whorls to invite comparison with *U. subornata*, and the same may be said of *U. besairiei* (Breistroffer), which also differs markedly in cross-section and coiling, but there are passage forms between *U. balmensis* and *U. rebouli* which have the general aspect of the English species. The resemblance is found to be superficial, however, when actual specimens are examined, the combination of characters being never the same, either the prominent tubercles of *U. balmensis* or the complex lobe line of *U. rebouli* being in evidence.

At a diameter of 40 mm. *U. boussaci* P. Fallot, from Majorca (P. Fallot, 1920, pp. 27–9, plate iii, figs. 3–4), resembles *U. subornata* at a similar size in its broadly rounded venter, nearly parallel whorl-sides and comparatively open umbilicus, but the whorls are not so stout, the ribbing less flexuous and with the primary portion more decidedly elevated and thickened towards the umbilicus. *U. boussaci* is further distinguished by its reduced secondary costation and its simpler type of suture-line, which lacks the markedly dependent auxiliaries found in that of *U. subornata*.

A blunter, coarser style of costation, with fewer secondary ribs to each primary distinguishes *U. clansayensis* (Jacob) from *U. subornata ;* there are also dimensional differences.

Beudanticeras dupinianum (d'Orbigny) is a fairly common fossil in the *mammillatum* zone in this country and conceivably might be mistaken for *U. subornata* if badly preserved. It is a more compressed and much less pronouncedly costate species with no tendency towards tuberculation at the umbilical border. The constrictions and accompanying ridges of *B. dupinianum* have a linguiform extension forward on the venter at all stages of growth in contrast to the very feeble forward bend shown in *U. subornata*.

Whether the " *Desmoceras* (*Uhligella*) sp." recorded by the brothers Destombes (1937, p. 102) from the *mammillatum* zone of Wissant, on the French coast opposite Folkestone, belongs to the present species (or even to *Uhligella* as here restricted) is uncertain, the specimen on which the record was based having been lost through enemy action during the late war. (Personal communication from M. J.-P. Destombes.)

Uhligella derancei sp. nov.

Plate XIX, figs. 2*a–d*, 3*a–b*

1868 *Ammonites Deshayesii* De Rance (*pars*) *non* Leymerie " Albian or Gault of Folkestone ", *Geol. Mag.*, v, p. 167.

1874 *Ammonites Deshayesii* Price *non* Leymerie. " Gault of Folkestone," *Quart. Journ. Geol. Soc.*, xxx, p. 362.

1875 *Ammonites Deshayesii* De Rance (*pars*) *non* Leymerie. *In* Topley, *Geology of the Weald*, p. 436.

1900 *Ammonites Deshayesi* Jukes-Browne (*pars*) *non* Leymerie. *Cretaceous Rocks of Britain*, vol. i, p. 82.

1923 *Beudanticeras subparandieri*, strongly costate variety. Spath, *Monograph Ammonoidea of Gault*, p. 95.

Material.—The holotype (G.S.M. 82908) and one paratype (G.S.M. 74874), both R. Casey Collection, Lower Gault, Bed II (*dentatus* zone, *intermedius* subzone) (*in situ*), foreshore reefs, East Wear Bay, Folkestone, and about five small nuclei from the same locality, found loose or of unrecorded horizon, but all in a mode of preservation consistent with derivation from Bed II. Also a single (decomposing) specimen from Folkestone in the De Rance Collection, Bed II suggested by preservation.

The type specimens, retaining most of the nacreous shell, both terminate at a septal surface. The holotype is complete down to the protoconch and has a small pathological disturbance of the ribbing on the venter at 20 mm. diameter, which does not, however, affect the subsequent formation of the shell. Dimensions are as follows :—

	Holotype (*G.S.M.* 82908).	*Paratype* (*G.S.M.* 74874).
Diameter in mm.	33	28
Whorl-height (in % of diameter) .	46	46
Whorl-thickness (in % of diameter) .	34	36
Umbilicus (in % of diameter) . .	24	23

Specific Description.—Whorl-section compressed, with flattened sides and evenly arched venter, the greatest thickness just above the rim of the umbilicus. Umbilical wall smooth, set nearly perpendicular to the sides, and with an abruptly rounded border, which is surrounded by nine to eleven bullate tubercles. Each bulla corresponds to a falcoid primary rib and two to three crescentic secondaries. The secondary ribs occupy the outer half of the flank, but frequently attempt to join up with the primary root, thus giving the impression of incipient bi- or trifurcation. Ribs continuous across the venter with a sinus forward which becomes less marked in the course of growth. Six or seven very shallow constrictions per whorl, with accompanying feeble bolster ribs, confined to the outer zone of the sides and the venter.

After three smooth serpental whorls the ornamentation is visible (in the holotype) on the umbilical shoulder at the early diameter of

3–4 mm. The ornamentation reaches its maximum vigour between 20 and 25 mm., after which the umbilical tubercles are gradually assimilated by the primary ribs, and the ribs begin to fade from the middle of the sides and on the siphonal line. The tubercles lose definition already at 30 mm. diameter, but available specimens are too small to show the final stages of decline in the ornamentation.

Growth striae across the umbilical rim with an obliquity forwards and thence run parallel with the costae ; they are picked out most easily on the inner third of the flank.

Suture-line simplified, with a deep, trifid, markedly asymmetrical first lateral lobe which tends to undercut the massive external saddle. Ventral and first lateral lobes of equal length at 10 mm. diameter, but ventral lobe eventually reduced in relative length.

Remarks.—This is a rare ammonite in the Gault at Folkestone and appears to be restricted to the *intermedius* subzone (Bed II), which has also yielded isolated examples of *Tetragonites*, *Desmoceras*, and *Brancoceras*—genera which are all typical of Southern European localities. It is my opinion that this is the ammonite recorded from this horizon by De Rance and Price as " *Ammonites Deshayesii* Leymerie ". In his paper on the " Albian or Gault of Folkestone ", De Rance (1868, p. 167) informs us that " Two distinct forms of *Ammonites Deshayesii* occur in the Lower Cretaceous series, one with a square flat back, the other with a rounded back. The former occurs in the zone of *Rhynchonella sulcata*,[1] and the sand seam in the zone of *Ammonites interruptus* ; the latter form in the Lower Neocomian clay of the Isle of Wight [i.e. the true *Deshayesites* of the (Aptian) Atherfield Clay] and the clay of the Lower Albian [*recte* Middle Albian], zone V [= Bed VII of the standard notation adopted from Price], at Folkestone ". A specimen of *U. derancei* in the De Rance Collection (G.S.M. 31346), dated 1868, is labelled as from Bed V [Bed VII] of

[1] De Rance uses this term for the basement-bed of the Folkestone Beds, in which is found the ventrally angular *Hypacanthoplites* of the *jacobi* subzone, not placed on record in this country until over 70 years after the appearance of De Rance's paper ! (See Casey, 1939, p. 365.) A specimen from Folkestone in the Price Collection (G.S.M. 1797), labelled " *Ammonites Deshayesii* ", is unquestionably a *Hypacanthoplites* from this very bed. The only ammonites known to me from the sand seam in the zone of " *A. interruptus* " (just above the Pyritic Band at the base of the Gault) are those recorded by Dr. Spath (1943, p. 734, footnote) as " *Hoplites*, including *H. dentatus* " (G.S.M. 83164–6). According to my determinations these ammonites belong to undescribed forms intermediate between *Hoplites* and one of its forerunners, *Pseudosonneratia*, and would answer to the appellation " *A. Deshayesii* " in the very wide meaning given it by De Rance. The stratigraphical significance of these specimens will be discussed at a later date, but it may be said at once that they indicate a lower horizon than that of *H. dentatus* and that their discovery modifies current views as to the subzonal representation at the base of the Gault at Folkestone.

It is necessary to add that the terms *zone* and *bed* as used by De Rance are interchangeable.

the Gault at Folkestone, though that part of the shell which is not decomposed retains the intense coloration and lustre peculiar to the pyrites-filled ammonites of Price's Bed II. This is the specimen which Spath has referred to as a strongly costate variety of *Beudanticeras subparandieri* (see synonymy). One may surmise that it was obtained from the foreshore reefs, where the dark clays of Bed II and Bed VII are readily enough confused. The true horizon of the ammonite must have been ascertained eventually by De Rance, for in tables showing the distribution of fossils in the Gault at Folkestone published subsequent to his 1868 paper (De Rance, 1875, p. 436 ; Jukes-Browne, 1900, p. 82) *Ammonites Deshayesii* is shown on the authority of De Rance as occurring in Bed II but not in Bed VII. Price also lists the ammonite from Bed II, though it is not represented among the Gault material registered under his name in the British Museum and in the Geological Survey Museum.

Uhligella derancei is an advanced form of *Uhligella* of the type of *U. balmensis* (Jacob) but is less ornate than that species ; it thus resembles some of the transitions between *U. balmensis* and *U. rebouli* mentioned above, particularly the syntype of *U. rebouli* which Breistroffer has designated *U. balmensis* var. *rencurelensis* (= Jacob, 1908, plate xiv (iv), fig. 3). A satisfactory comparison with that variety cannot be made until its inner whorls have been figured, but it is less evolute than the present species and has the complex suture-line of *U. rebouli*. An Escragnolles example in the British Museum (B.M. 37701), similarly transitional between *U. balmensis* and *U. rebouli*, has dimensions 39, ·46, ·31, ·24, and differs from *U. derancei* only in being more boldly ribbed and in retaining the umbilical tubercle to a larger diameter.

The form here described differs from *U. subornata* sp. nov. chiefly in its almost obsolete constrictions and its simplified suture-line, which lacks the sharp decline of the auxiliaries towards the umbilicus ; the style of ornamentation is also more reminiscent of *Cleoniceras quercifolium* (d'Orbigny).

Of special importance is the relationship between *U. derancei* and *Beudanticeras subparandieri* Spath, a variable species of the *cristatum* subzone (Bed VIII). Unfortunately, the inner whorls of the holotype of this species are corroded, but there are available a number o topotype specimens (e.g. G.S.M. 83104 and S.M. B 30797) which may be assumed with a reasonable degree of confidence to be conspecific with the holotype. In these specimens the feeble primary ribs reach right down to the rim of the umbilicus but do not become tuberculated, even on the inner whorls. *U. derancei* is readily distinguished from this form by its much coarser, tuberculate, ornamentation, although the two species are very similar in general habitus and are almost

identical in sutural characters. Indeed, among the variants of *B. subparandieri* in the *cristatum* subzone is an extreme form which may be regarded as transitional between the two species (Pl. XIX, figs. 4*a–b*). The ribbing of this form is a good deal more pronounced than that of the typical *B. subparandieri* and the primary ribs are feebly nodate in the umbilical region ; it thus stands about halfway between *Uhligella* and *Beudanticeras*. The coarse specimen of *B. subparandieri* (B.M. 796*a*) mentioned by Spath (1923, p. 62), since decomposed and thrown away, was probably a similar passage-form.

Now, *B. subparandieri* may be linked just as convincingly with the smooth *B. beudanti* (Brongniart), which ranges from the condensed Bed VIII to Bed XI at Folkestone, so that having regard to the stratigraphical evidence it does not appear unreasonable to suggest that this morphological series from *Uhligella derancei* to *Beudanticeras beudanti* denotes actual biological continuity, the lineage showing progressive reduction in ornamentation and whorl-thickness, correlated with increased complexity of the suture-line. It is opportune here to point out that the highly ornate *U. balmensis* occurs already in the *nodosocostatum* zone (Breistoffer, 1947, p. 7) and therefore precedes the closely connected but morphologically simplified *U. rebouli*, which in turn leads on to *Beudanticeras*. When reviewing the generic succession in the Desmoceratidae Whitehouse (1926, p. 218) also offers the opinion that *Uhligella* has given rise to species of *Beudanticeras*. Spath, however, inclines to the belief that in this genus, as in all the Desmoceratidae, smoothness is an original feature (Spath, 1923, pp. 31–2).

Uhligella derancei var. *erugata* nov.

This varietal name, which it may be desirable to employ in a specific sense on discovery of more complete material, is applied to a form which differs from the typical *U. derancei* in the following respects : the whorl-section is more compressed, the costation less bold, with the primary ribs delicately emphasized rather than tuberculate around the umbilical region ; the venter is almost completely smooth already at 15 mm. diameter. A specimen collected by L. F. Spath (G.S.M. 83100), figured Plate XIX, fig. 3*a–b*, may be taken as the type of the variety. There are two other specimens (B.M. C 32865 and C 32869),[1] and all three are preserved as internal moulds in pyrites

[1] Specimens C 32868 and C 32869 in the British Museum are accompanied by a note in Dr. Spath's handwriting, which I quote with the author's permission : " Probably a new species of *Beudanticeras*, resembling *Cleoniceras devisense*, apparently from Bed II, but never found by *myself* and therefore not described. A '*pre-subparandieri*' form." In the Gault Monograph (1942, p. 693) specimen C 32869 is described as a " *devisensis*-like undescribed species of *Cleoniceras* ". The " slightly more inflated form " (B.M. C 32867) referred to in connection with this specimen is a nucleus of the typical *Uhligella derancei*.

and almost certainly came from Bed II, as the label " Black Bed " on one of them would indicate. The two larger specimens have dimensions as follows :—

	G.S.M. 83100.	*B.M. C* 32865.
Diameter in mm.	25	33
Whorl-height (in % of diameter) .	48	47
Whorl-thickness (in % of diameter) .	32	30
Umbilicus (in % of diameter) . .	25	25

Two small examples (B.M. C 32866 and C 32868) combine the lateral aspect of the typical form with the whorl-thickness and smooth ventral area of the var. *erugata*. This variety is of especial interest because it connects *Uhligella* with such forms as " *Desmoceras* " *bicurvatoides* Sinzow (1909, plate ii, figs. 7–18) and its ally *Cleoniceras? devisense* Spath (1923, p. 94). These two species represent a group which, although too imperfectly known to be separated generically, appears to have been derived from *Uhligella* independently of *Cleoniceras*, which it replaces in time. The var. *erugata* is distinguished from this group only by the persistence of vestigial constrictions beyond the ephebic stage and the consequent slight irregularities in the ribbing.

III. REFERENCES

ANDERSON, F. M., 1938. Lower Cretaceous Deposits in California and Oregon. *Geol. Soc. Amer. Special Papers No.* 16.

BREISTROFFER, M., 1936. (*In* Besairie) Recherches géol. Madagascar. I, Géol. du Nord-Ouest. *Mém. Acad. Malgache.*

—— 1947. Sur les Zones d'Ammonites dans l'Albien de France et d'Angleterre. *Trav. Lab. géol. Univ. Grenoble*, xxvi, 1–88.

BURCKHARDT, C., 1925. Faunas del Aptiano de Nazas (Durango). *Inst. Geol. de Mexico, Bol. No.* 45.

CASEY, R., 1939. Upper Part of Lower Greensand around Folkestone. *Proc. Geol. Assoc.*, l, 362–378.

CHAPUT, E., 1920. Les Desmoceratidés du Paléocrétacé. Revision du Genre *Desmoceras*. *In* Kilian : Contrib. Étude Céphal. Paléocrét. S.-E. France. *Mém. Explic. Carte géol. dét. France*, 167–188.

DE RANCE, C. E., 1868. On the Albian or Gault of Folkestone. *Geol. Mag.*, v, 163–171.

—— 1875. Distribution of Fossils in the Gault at Folkestone. *In* Topley : Geology of the Weald. *Mem. Geol. Surv.*, 434–6.

DESTOMBES, J.-P. and P., 1937. Note sur le Gault de Wissant. *Ann. Soc. géol. Nord.*, lxii, 98–113.

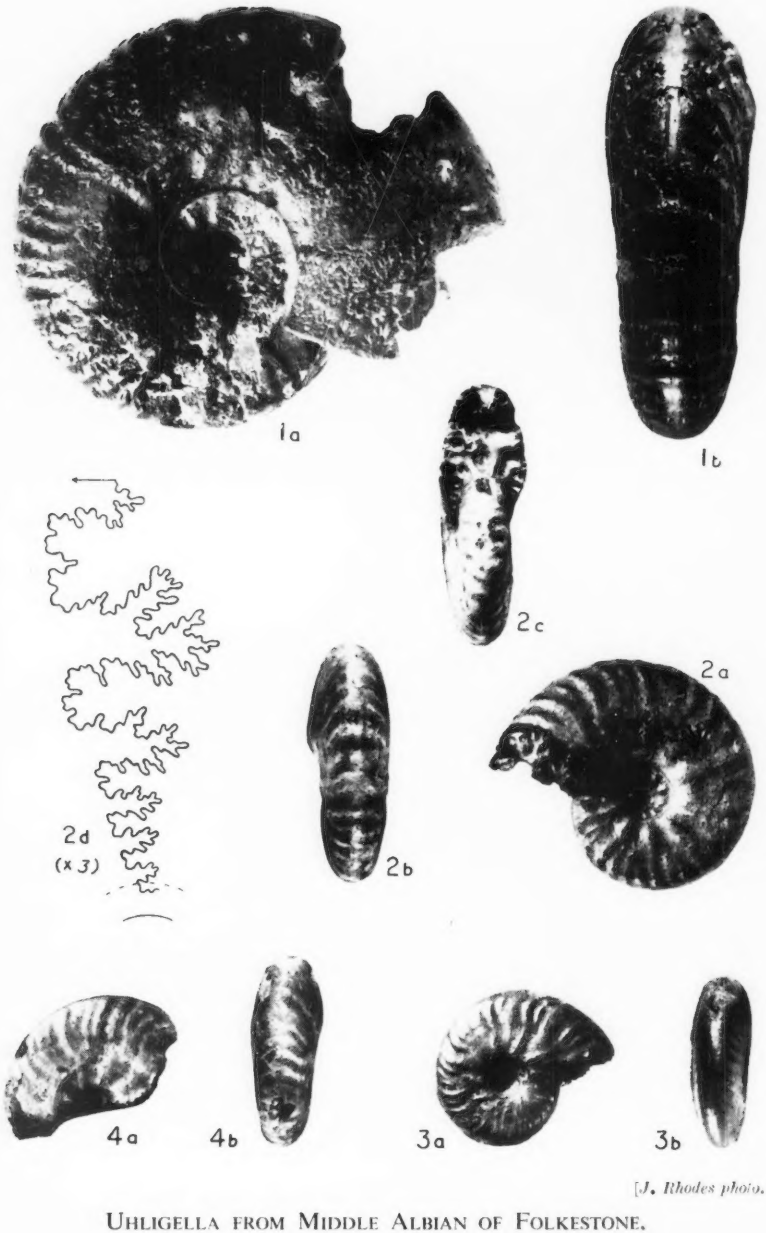
DOUVILLÉ, H., 1916. Une Famille d'Ammonites, les Desmoceratidés, etc. *C.R. Acad. Sci.*, Paris, clxii, 369–373.

DOUVILLÉ, R., 1911. *In Palaeontologia Universalis*, 3e ser., fasc. iii, p. 218*a*.

FALLOT, P., 1910. Sur Quelques Fossiles Pyriteux du Gault des Baléares. *Trav. Lab. géol. Univ. Grenoble*, ix, 62–90.

—— 1920. La Faune des Marnes Aptiennes et Albiennes de la Region d'Andraitz, Majorque. *Trab. Mus. Nac. de cienc. Nat.*, ser. Geol. No. 26 (Madrid), 1–68.

JACOB, C., 1905. Étude sur les Ammonites et sur l'Horizon stratigraphique du Gisement de Clansayes. *Bull. Soc. géol. France*, 4e ser., v, 399–432.



[*J. Rhodes photo.*

UHLIGELLA FROM MIDDLE ALBIAN OF FOLKESTONE.

JACOB, C., 1907. Études paléontologiques et stratigraphiques sur la partie moyenne des terrains crétacés dans les Alpes françaises. *Thèse Trav. Lab. géol. Univ. Grenoble*, viii, fasc. 2, 280–590.

—— 1908. Études sur Quelques Ammonites du Crétacé Moyen. *Mém. Soc. Géol. France*, Paléont., xv, No. 38.

JUKES-BROWNE, A. J., 1900. Cretaceous Rocks of Britain. Vol. I, Gault and Upper Greensand of England. *Mem. Geol. Surv.*

KILIAN, W., 1907. Unterkreide (Palaeocretacicum). *In* Frech : *Lethea Geognostica*, II, Mesozoic Vol. III, Kreide. Lief. I, 1–168.

PERVINQUIÈRE, L., 1907. Études de paléontologie tunisienne. I, Céphalopodes des terrains secondaires. *Carte géol. de la Tunisie.*

PRICE, F. G. H., 1874. On the Gault of Folkestone. *Quart. Journ. Geol. Soc.*, xxx, 342–368.

ROMAN, F., 1938. *Les Ammonites jurassiques et crétacées : Essai de Genera.* Paris.

SINZOW, J., 1909. Beiträge zur Kenntnis des südrussischen Aptien und Albien. *Vehr. russ.-kais. Min. Ges. St. Petersb.*, xlvii, 1–48.

SPATH, L. F., 1923–1943. A Monograph of the Ammonoidea of the Gault. *Palaeontographical Society, London.*

WHITEHOUSE, F. W., 1926. The Cretaceous Ammonoidea of Eastern Australia. *Mem. Queensland Museum*, viii, pt. 3, 195–242.

EXPLANATION OF PLATE

All Figs. natural size, except Fig. 2*d*

FIG. 1.—*Uhligella subornata* sp. nov. Holotype (R. Casey Collection, G.S.M. 70442). Side view (*a*) and peripheral view (*b*). Folkestone Beds (Mammillatum bed), Middle Albian, *mammillatum* zone, *monile* subzone. Foreshore reefs just east of Copt Point, Folkestone.

FIG. 2.—*Uhligella derancei* sp. nov. Holotype (R. Casey Collection, G.S.M. 82908). Side view (*a*), peripheral view (*b*), and apertural view (*c*), with external suture-line (*d*) enlarged × 3. Lower Gault, Bed II (*dentatus* zone, *intermedius* subzone). Foreshore reefs, East Wear Bay, Folkestone.

FIG. 3.—*Uhligella derancei* sp. nov., var. *erugata* nov. Type of variety (L. F. Spath Collection, G.S.M. 83100). Side view (*a*) and peripheral view (*b*). Gault, Folkestone. Found loose, but presumably from Bed II.

FIG. 4.—*Uhligella* sp. ? (L. F. Spath Collection, G.S.M. 83101). Side view (*a*) and peripheral view (*b*) of part of the inner whorls of a large fragmentary specimen transitional between *Uhligella derancei* sp. nov. and *Beudanticeras subparandieri* Spath. Lower Gault, Bed VIII (*lautus* zone, *cristatum* subzone). Folkestone.

Hilt's Law and the Volatile Contents of Coal Seams

By O. T. Jones

(*Concluded from p. 312*)

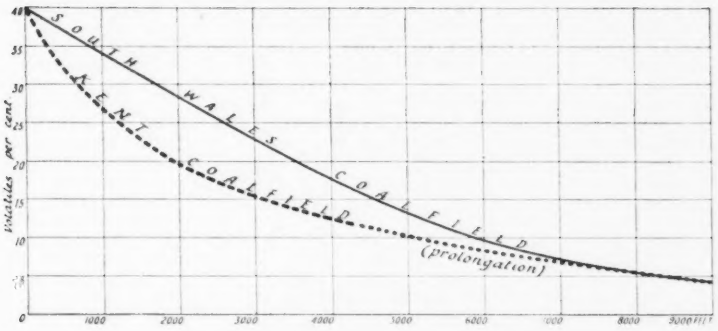
General Relations between Volatile Percentages and Depth

Arbitrary relations between volatile percentage and depth of the seams can be established readily for both the South Wales and Kent coalfields by means of the Hilt rates: this is perhaps most clearly indicated by the South Wales sequences, which are considered first. If we take as a horizontal datum plane a seam which contains 40 per cent of volatiles we can calculate from the Hilt rate the depth for any given sequence at which the Nine-Foot seam would lie below that datum. Thus, at New Bridge the recorded volatile content of the Nine-Foot seam is 28; a least squares solution gives 26·7; adopting a value of 27 and a Hilt rate of 5·32, that seam would be 2,440 feet below the datum. At Treherbert the recorded volatile is 11, while a least squares solution gives 11·5; the depth of the Nine-Foot seam below the datum would thus be 5,400 feet. It is clear, therefore, that if the 40 per cent seam were regarded as a horizontal plane, depression was at one time more rapid in the west than in the east. It is known that a rapid increase in the thickness of the measures below the Pennant Sandstone takes place westward, but the difference of 3,000 feet indicated above is much more than occurred by differential warping during the formation of the lower measures among which the Nine-Foot seam lies. The tendency which is evident, however, in these lower measures must have continued into much later Coal Measure times, in which case a 40 per cent datum was itself warped down.

It is possible by thus making use of the Hilt rates to find an arbitrary volatiles/depth relation on a line such as AE along the whole length of the coalfield between New Bridge and the Gwendraeth Valley. This is shown in the section, Text-fig. 3. From the general uniformity of the rates not only along the above line but for at least 6 miles on each side of it, one may provisionally associate with each isovol in that area a particular depth of the Nine-Foot seam measured down from the 40 per cent seam as a datum. From the section and the isovol map it would thus be possible to construct an isobath map showing the depth at every point below the datum.

Even a 40 per cent seam started life, however, as vegetation in a peat swamp; what the volatile content of such an organic layer would be is guesswork but it is not improbable that it was 80 to 90 per cent at least. If for purposes of argument we assume that the Hilt rates found for the eastern sequences hold for the interval between the 40 per cent seam and the surface, we find (using the average Hilt rate 5·37) that the cover on the 40 per cent seam would be about 7,450 feet if the peat

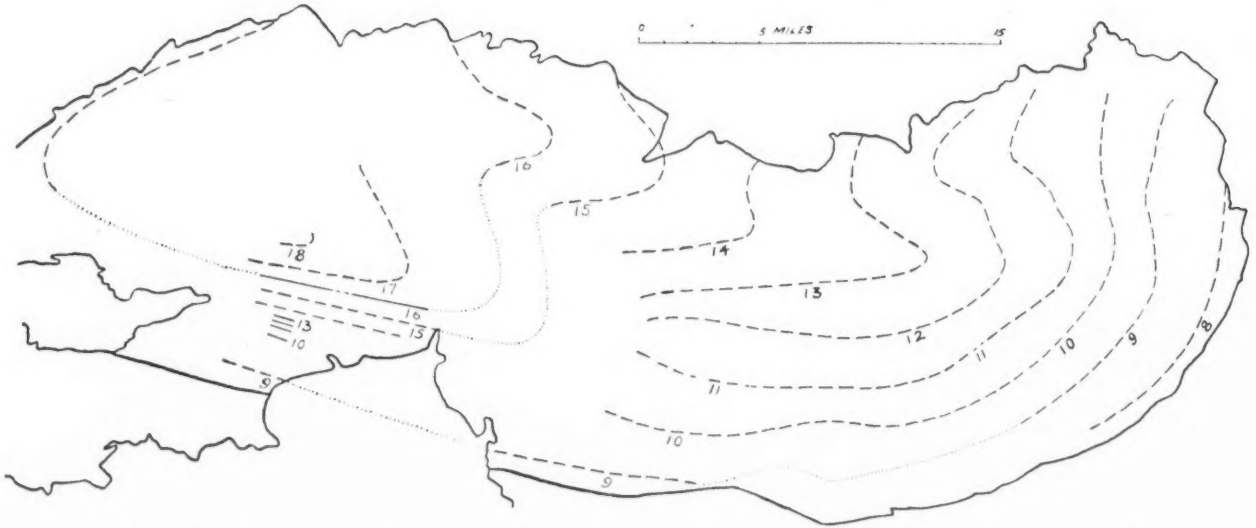
had a volatile percentage of 80 and about 9,300 feet if its content was 90 per cent. The only check that I know of on such figures is that given by a borehole at Notown, Greymouth, New Zealand, which is referred to by H. W. Wellman, 1948. This borehole " passed without apparent metamorphic break from peat in the surface beds through sub-bituminous coal at 3,000 feet to bottom in high volatile bituminous coal



TEXT-FIG. 3.—Relation between volatile contents of coal seams and depth below a given datum in (*a*) South Wales along an E.–W. line and (*b*) the Kent Coalfield on a N.W.–S.E. line.

at 7,000 feet ". In a letter Wellman states that the exact depth to the bottom seam was 6,893 feet and from analyses which he kindly included, the volatile content of the seam on an ash-free dried basis was exactly 50 per cent. If we adopt figures of 80 or 90 as possible volatile contents of peat, the average rate between this seam and the surface is 4·35 per cent per 1,000 feet or 5·8 per cent respectively. Extrapolating these rates would suggest that the cover on a 40 per cent seam under similar conditions would be 8,600 or 9,200 feet. There is closer agreement between these figures and the above estimates for South Wales than we have any right to expect, but it suggests that the estimate of the cover on a 40 per cent seam in South Wales is not wildly wrong.

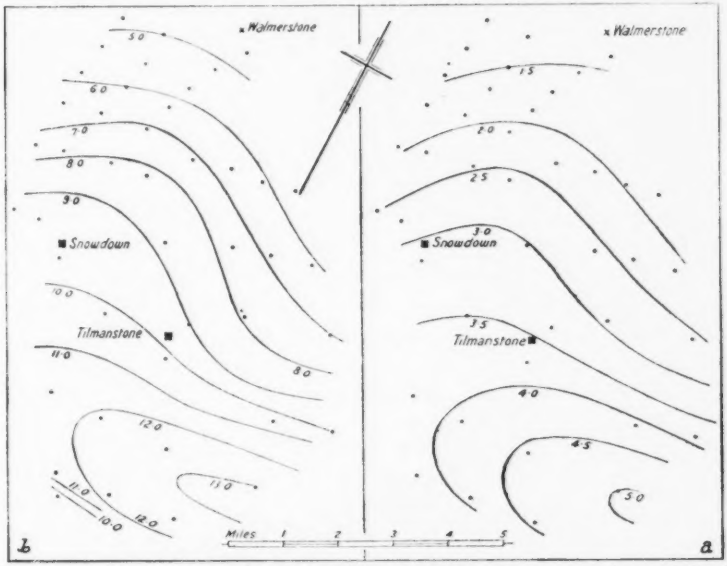
If, therefore, we added a round figure of 8,500 feet to the depth of the Nine-Foot seam below the 40 per cent datum, a 5 per cent anthracite would have been covered by nearly 17,000 feet of sediments. It is improbable, however, that the cover on a 40 per cent seam would have been uniform over the coalfield. Text-fig. 4 shows an isobath map giving the approximate depths to which the Nine-Foot seam was probably buried below the surface at the end of the Carboniferous. By reason of subsequent compaction the original depth may have been 2,000–3,000 feet at least greater than the above figure. In the western part of the field about 4,000 feet has been added



TEXT-FIG. 4.—Isobath map showing probable maximum depth of cover on the Nine-Foot seam, South Wales Coalfield. Figures indicate depth in thousands of feet.

to the cover on the Graigola seam to give the probable cover on the Nine-Foot seam.

By combining the Hilt rates with the isovols the same method can be used in the Kent coalfield to determine either the depth of some horizon below a 40 per cent datum or approximately the depth of



TEXT-FIG. 5.—*a* Approximate isobaths of Millyard seam at close of Coal Measures deposition.

b Approximate isobaths of Millyard seam below an assumed datum plane of a seam containing 40 per cent of volatiles.

that horizon below the surface at the end of the Carboniferous (see Text-fig 3 for comparison with the relation in South Wales).

The horizon of the Millyard seam which is about 800 feet above the base of the coal measures is chosen. Taking the intersection of isovol 25 with the Hilt rate 10, the difference between the volatiles of the datum at 40 and the Millyard seam at that point is 15, which divided by 10 per thousand gives a depth of 1,500 feet. By using in this way the remaining intersections the contoured isobath map Text-fig. 5*a* is obtained. Since the depth below the datum at any point on a given isovol varies inversely as the Hilt rate it is obvious that the trends of the isobaths must bear a resemblance to those of the lines of equal Hilt rates. This map brings out clearly the original trough-like form which the basin assumed during the deposition of the measures. An even more interesting result in comparison with South Wales is obtained if the Hilt rates are used to calculate the possible total cover on the Millyard seam. The result is shown in Text-fig. 5*b* where the depths

at the intersections of Hilt rates and isovols are in thousands of feet. This isobath map portrays a deep geosyncline with a sharply defined east and west axis and so far as the indications go a steeper slope on the south than on the north. At Oxney near the axis where the Millyard seam might be expected to have a volatile content just below 15 per cent, if the effect of cover is the same as in South Wales it would take an additional cover of 3,500 feet to produce a 5 per cent anthracite seam giving a total cover at that point of nearly 18,000 feet. If, as in South Wales, we add a cover of 8,500 feet on the 40 per cent seam the result at Oxney would be a depth of burial of about 14,000 feet.

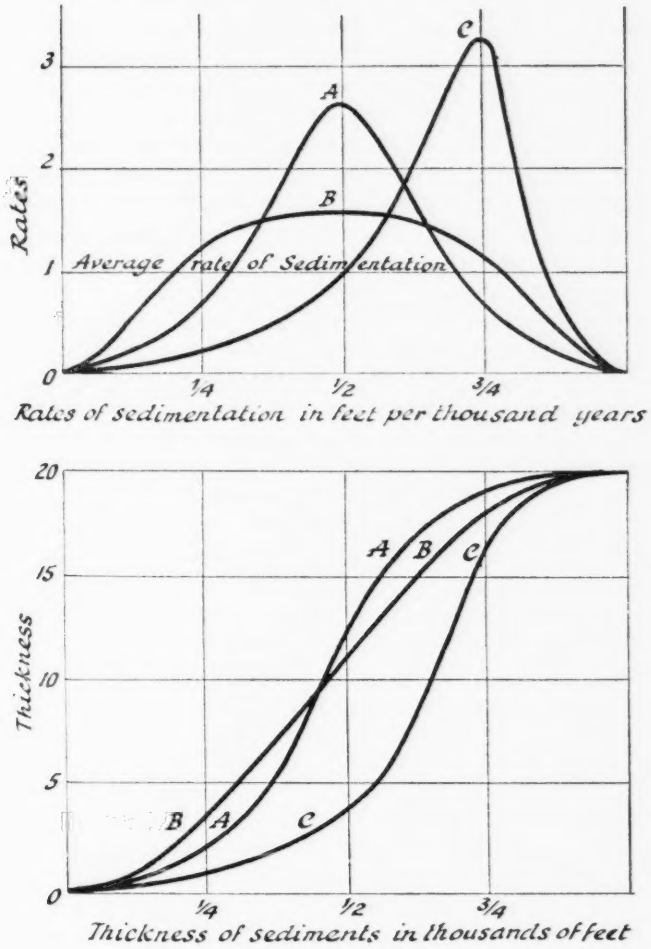
It is interesting to compare these deductions with the conclusions drawn by H. W. Wellman, 1948, from his study of the metamorphic gradients in this field which was based on the data published by Dines. He noted that the metamorphic gradient changed considerably from north-west to south-east and concluded that at the centre of the syncline the original depth of the base of the coal measures was about 14,000 feet. It may be added that if a coal seam occurred at the base its volatile content there would be about 10 per cent, which suggests that the cover on a 5 per cent anthracite seam in the Kent coalfield might be expected to be about 17,500 feet. Wellman estimated that at the north-east (? north-west) margin of the field the cover would be only about 9,000 feet ; there is reason to believe that even this latter figure is an over-estimate. If Wellman's metamorphic gradient is doubled it gives approximately the depth of the base of the coal measures at those points. He concluded (p. 508) also that " the progressive rise of the isogeotherms through the beds and the progressive increase in weight of overburden caused each seam to be progressively metamorphosed. Coal metamorphism was completed when the isogeotherms reached their highest level ". It will be observed that Wellman attributed the metamorphism to a rise of temperature and to an increasing weight of overburden.

Changes Induced in Coal by Progressive Burial

It is of interest to inquire next how increasing temperature and pressure may have controlled the changes which took place in layers of vegetation between their accumulation at the surface and their subsequent burial to varying depths. If we consider a series of coal seams, S_1, S_2, etc., which lie at a depth of several thousand feet below the surface, let V_1, V_2, etc., represent the volatile contents of those seams at the present time and Y_1, Y_2, etc., their depths below the original surface. Hilt's law expresses the relation

$$h = -\frac{V_1 - V_2}{Y_1 - Y_2}$$

the negative sign indicating that the volatiles decrease in depth. The depth Y_1 was attained by depression from the original surface on



TEXT-FIG. 6.—Diagrammatic representation of varying rates of sedimentation in a Coal Measures geosyncline, and the cumulative thickness resulting from these rates.

which S_1 accumulated followed by the re-establishment of that surface level by sedimentation; the difference $Y_1 - Y_2$ between the two seams S_1 and S_2 corresponds to an interval of time multiplied

by the rate of depression or what is the same thing the rate of sedimentation which maintained the level of the surface prior to and during the formation of S_2. The rate of sedimentation varied from one part to another of a given area of deposition which subsequently became a coalfield. As most of these coalfields were geosynclines the depression and consequent sedimentation was greater in the axial than in the marginal region. If, however, we select some particular place, say near the axial region, and consider its depression throughout the history of the basin, sedimentation may have begun at a zero rate, then increased to a maximum, finally falling off to zero at the end of the Carboniferous period when depression began to give way to uplift of the area. While this assumption that sedimentation began at a very slow rate probably applies to the geosyncline as a whole it is possibly not strictly true for the Coal Measures which are the last phase in the formation of the Carboniferous geosyncline and therefore inherited a particular rate of sedimentation from the immediately preceding formation, the Millstone Grit. Where, however, as in the Kent coalfield the Coal Measures rest with a non-sequence upon Carboniferous limestone or older beds the assumption is probably true. A, B, and C, Text-fig. 6, represent different ways in which the rates of sedimentation might have varied within the full period of accumulation of the Coal Measures. In A the maximum rate was attained towards the middle of the period and the rates before and after the maximum were similar. In B the rate remained during half the life of the Coal Measures near the maximum, while in C the culminating point was reached late in the history of the basin and fell off rapidly to the end. The corresponding increase in thickness are shown in Text-fig. 6. The total thickness represented by the areas of the figures is the same for A, B, and C. Since in many geosynclines uplift began on the border of a basin while deposition was still continuing within the basin the products of erosion transferred from the rising region to the still sinking basin accelerated the process of depression and raised the rate of sedimentation ; the curve C may represent that type of behaviour.

According to the depth of burial theory the organic matter of the peaty swamp began to decay as soon as the plants died and it is generally agreed that the process was actively promoted by micro-organisms ; White, 1908, gives a good account of this stage of coal formation. As the organic layer became buried further changes occurred under anaerobic conditions. Decay resulted in a loss of volatile matter ; if a seam stayed for a long time near the surface oxidation may also have caused loss of volatiles and it is known that different samples of surface peat exhibit a considerable range of volatile content (see Raistrick and Marshall, 1939, p. 224). The effect of micro-organisms ceased when the temperature became too high for their survival

but it is not impossible that lignites may have formed at a depth of some thousands of feet mainly by bacterial action. At greater depths further changes must be attributed to the higher temperatures at those depths ; in that case chemical activity controlled by the physical conditions must have been the chief cause of loss of volatiles. The seams S_1, etc., reached at some time equilibrium with their environment so that their volatile contents became, as it were, frozen and little if any change has taken place subsequently, however long a period of time may have elapsed. The difference between the volatiles V_1 and V_2 must therefore be attributed to the difference in depth between Y_1 and Y_2 and the Hilt rate is a measure of this effect.

The differences of opinion between proponents of the two main theories of the devolatilization of coal turn largely on the period at which the volatiles became frozen. Advocates of the depth of burial theory claim that the devolatilization of British coals was almost if not quite completed before the post-Carboniferous movements became active, but those who believe in tectonic effects maintain that this did not occur until the coalfields were subjected to earth movements leading to folding and faulting. It is doubtful if any advocate of the tectonic theory would hold that no change occurred in the seams during their burial so that the point at issue between rival theories is the period and manner of " finishing off " of the seams.

The process of change from peat to anthracite appears to be so continuous that no one can point convincingly to any composition or volatile content which divides off the effects of one agent or manner of decomposition from those of another.

It is assumed therefore that when a seam such as S_1 arrived at its final depth, it had already been divested of a large fraction of its initial volatile content. Different coal seams of a given volatile content are so nearly of the same composition that they fall within a very narrow band of composition or volatile contents (Hickling, 1932, and Trotter, 1948). One can therefore resort to the fiction that a number of different seams now found at increasing depths may be made to represent the history of one particular seam at different stages of its descent below the surface where it originated in a swamp. It is not thereby assumed that while occupying the positions Y_1, Y_2, etc., this seam had the final volatile contents V_1, V_2, etc.

The volatile content as determined on a sample of coal in a laboratory under standard conditions is not the whole of the potential volatiles in that sample, for if it were heated for a longer period or for the same period at a higher temperature than the standard temperature of 925° C., more volatile matter would be given off. To expel the whole of the volatiles, leaving a residue of carbon only, would probably require the heat of an electric arc. Thus the volatiles driven off at

925° represent that fraction of the total volatiles which is *expendable* under the conditions of the experiment.

When the seam S_1 reached the level Y_1 it had already lost a large portion of its initial volatile content, and if it stayed in that environment for a long time it would ultimately reach the volatile content V_1 or near thereto, at which it was thereafter frozen. If, however, after that time it was depressed to Y_2 and remained there permanently its volatile content would become V_2. In changing from the depth Y_1 to the depth Y_2, the seam at Y_1 had an expendable volatile content v_1 which, if the descent took a very long time, would approach V_1–V_2 as a limit ; though, in general, v_1 might be somewhat less than V_1–V_2. Let us then assume for simplicity that the seam is depressed suddenly from Y_1 to Y_2, so that it arrives at Y_2 with its expendable volatile content v_1 intact. At the new level Y_2 reaction sets in under the changed environmental conditions, leading to a using up of part or the whole of this expendable volatile matter.

The rate at which the volatile content changed with time must be presumed to have depended on the temperature and probably also on the pressure and both of these are functions of the depth ; it is also probable that in accordance with the law of mass action the rate was proportional to the amount of volatile matter remaining to be expended at a given time. These conditions lead to an exponential relation such that

$$v = v_1 \epsilon^{-\lambda t}$$

where λ represents the combined effect of the chemical and physical factors and may be regarded as a sort of decay factor. If the seam remained at this level Y_2 for a time short of infinity, it would pass through various stages such as that at each stage some fraction $\frac{1}{m}$ of v_1 remained unspent. If, for example, m is taken as 2 this corresponds to what is called the half-life of v_1 and the time required to reach it is the " half-life period " which is given by

$$T = \frac{\log_\epsilon 2}{\lambda} \text{ or } \frac{\cdot 69}{\lambda}$$

If, on the other hand, m were taken as 10, T would be $\frac{\log_\epsilon 10}{\lambda} = \frac{2 \cdot 3}{\lambda}$ or just over three times as long. The change of depth $Y_1 - Y_2$ on this view is, however, the amount by which the seam was depressed by sedimentation at the surface while these reactions were going on. If instead of being depressed suddenly the seam descended gradually from Y_1 to Y_2 the reactions discussed above would probably not be much

altered, but the change of depth $Y_1 - Y_2$ would represent the amount of sediment which was laid down at the surface in the time required for the expendable volatile content of the seam to be reduced to $\frac{1}{m}$ of its initial amount v_1. If we call the average rate of sedimentation S, then $Y_1 - Y_2 = ST'$ and T' is proportional to $\frac{\log_\epsilon m}{\lambda}$. The Hilt rate is thus seen to be proportional to $\frac{\lambda}{S}$. If we consider stages such that the changes of volatile content from one depth to another were the same, the Hilt rate would measure the relative effect, on the one hand, of the chemical and physical factors at the level of the seam and, on the other, the rate of sedimentation at the surface at that stage. Thus, if we compare two places, one near the margin of the geosyncline and the other near the axis, and suppose that S near the margin is one-third of its value near the axis then for equal differences of volatile percentages and at the same depths below the surface the Hilt rate in the one case would be three times that in the other. We have some such relation if we compare the north-west part of the Kent Coalfield, as at Stodmarsh, with the axial region, as at Oxney.

It would appear therefore that the Hilt rate may be controlled largely by the rate at which the seams were depressed by sedimentation at the surface during successive stages of devolatilization and *not by the rate of sedimentation which prevailed at the time when the seams were laid down.* Since the rate of depression may have varied from time to time and from place to place the Hilt rate may thus reflect the geological history of sedimentation in the coalfield.

This interpretation of the Hilt rate as a reflection of the varying history of sedimentation within a given coalfield both in space and in time accounts readily for the changes of rate observed in the Kent Coalfield. Towards the north-west margin sedimentation was slow and the Hilt rates high whereas near the axis the reverse was true. It is not impossible that the difference between the Hilt rates at Stodmarsh and Oxney are due solely to varying rates of sedimentation and that the chemical-physical factors remained almost unchanged throughout a depth of burial of 10,000 feet. It is unlikely, however, that there was such a difference in sedimentation between points only 10 miles apart, and in such a case the chemical-physical factors must have diminished as the depth of burial increased. In the South Wales Coalfield, however, we have to consider this interpretation in relation to two regions of widely different behaviour. In the eastern half of the coalfield the Hilt rates are uniform in spite of the fact that the sedimentation increased

from east to west. Thus if h varies as $\frac{\lambda}{S}$ then since it is clear that S increased from east to west, it would appear that λ must have diminished in that direction in order to preserve a constant ratio. This is at first sight contrary to what might have been expected, since the greater depth of burial and the greater temperature to which the seam must have been exposed in the western part of the region might have been expected to increase the chemical activity. The case is paralleled, however, as we have seen, in the Kent Coalfield, where the decay factor was probably greater under the shallow cover than under the deep cover.

In the three western sequences in South Wales, however, the Hilt rate drops so markedly, attaining at the Gwendraeth Valley a rate less than one-fifth the rate at Treherbert, that this explanation is not fully satisfactory. It may be noted that the effect of diminished volatile content, or the "law of diminishing returns", has already been taken into account in deriving the exponential formula since that is based on the assumption that the loss of volatiles at any time is proportional to the total volatiles expendable at that time. It can hardly be assumed that the rate of sedimentation at the Gwendraeth Valley increased to anything like five times the rate at Treherbert; the diminution in the Hilt rate must therefore be attributed to a marked decrease in the rate of the combined chemical and physical effects expressed by the decay factor λ. The conclusion that some diminution in this factor occurred with increasing depth of cover has already been reached in considering the six eastern sequences and is supported by the variation of Hilt rates in the Kent Coalfield. A further diminution in the factor between Treherbert and the Gwendraeth Valley is therefore to be expected as the depth of burial increased. Whether, however, the decrease to less than one-fifth can be accounted for by that explanation is very doubtful in view of the relative suddenness of onset of the change in Hilt rates between Treherbert (5·26) and Resolven (3·31) in a distance of just over 6 miles. It is, in fact, unlikely that the rate of sedimentation at Gwendraeth Valley was ever twice as great as at Treherbert.

Where the marked change sets in the volatile percentages are below 16 and the lower seams even at Resolven are of anthracite rank. Since the final stages of devolatilization result in a progressive loss of hydrogen, whereas the earlier stages are indicated mainly by a loss of oxygen, it is possible that the considerably lowered rate of chemical-physical activity near or within the anthracite range is due to a *change in the character of the reactions* whereby a given temperature has relatively less effect in reducing the volatile content than at the higher levels.

The Factors Controlled by Depth of Burial

Temperature.—The reactions that take place in a coal seam at depths great enough to allow us to discount the effect of micro-organisms are presumably some function of temperature which may be assumed to increase in more than linear ratio with rise of temperature. As an illustration of a function exhibiting this behaviour we may take the vapour pressure of water, which is ·12 bars at 50° C., 1·01 at 100°, 15·55 at 200°, and 46·94 at 260° C. (*Handbook of Physical Constants*, p. 210); one bar is about one normal atmosphere. It is not implied that the actual function of temperature which governs the coal reactions behaved like the pressure of water vapour though it is not unlikely that this along with the pressure of other vapours generated by the decomposition of the coal plays a part. The great difference in activity caused by a rise of temperature of a few degrees above the boiling point of water brought about by a pressure of a few atmospheres is seen in an ordinary pressure-cooker.

Pressure.—It has been commonly assumed that the high pressure which prevails at a depth in sediments must have caused a loss of volatile matter in coal seams. The effect is apparently regarded as comparable with the squeezing out of water from a muddy sediment under load and, in so far as it is known that coal seams do lose moisture with increasing rank and depth of burial, pressure probably plays the same role in a coal-seam as in an ordinary fine-grained sediment. The reactions between the chemical constituents of a coal seam which lead to a loss of carbon, oxygen, and hydrogen in certain proportions are, however, chemical reactions, and without knowing precisely what they are it is probably safe to assume that they result in an increase in the aggregate volume of the coal and its products of decomposition. If this is a correct assumption, then pressure would undoubtedly retard the reactions by making it difficult to get rid of the volatile products. If the environment was such that none of these products could escape the reaction would be totally inhibited.

Mr. Maurice Hill informs me that a high explosive such as dynamite, which like a coal contains the oxygen necessary for its decomposition, will not explode below quite a moderate depth of water on account of the inhibiting effect of pressure.

Pressure may therefore inhibit the reaction altogether, in which case burial below a certain depth cannot diminish the volatile content of a seam below a given amount or it may greatly retard the reaction by preventing the easy escape of volatiles. In view of the progressive change in the volatile contents of coal seams down to very low values total prohibition is unlikely. The other role would diminish the decay factor λ and thus lead to a low Hilt rate at a great depth, whereas if the conditions are such that the products at any level can escape freely,

the decay factor and consequently the Hilt rates are high. Pressure may exert such a retarding effect through a reduction of the minute channels which communicate from one pore to another in a fine-grained sediment. Professor Illing, 1944, remarked that " there was considerable evidence that compaction of sediments is in some cases brought to a stage of temporary equilibrium by the inability of the fluids to force an exit ".

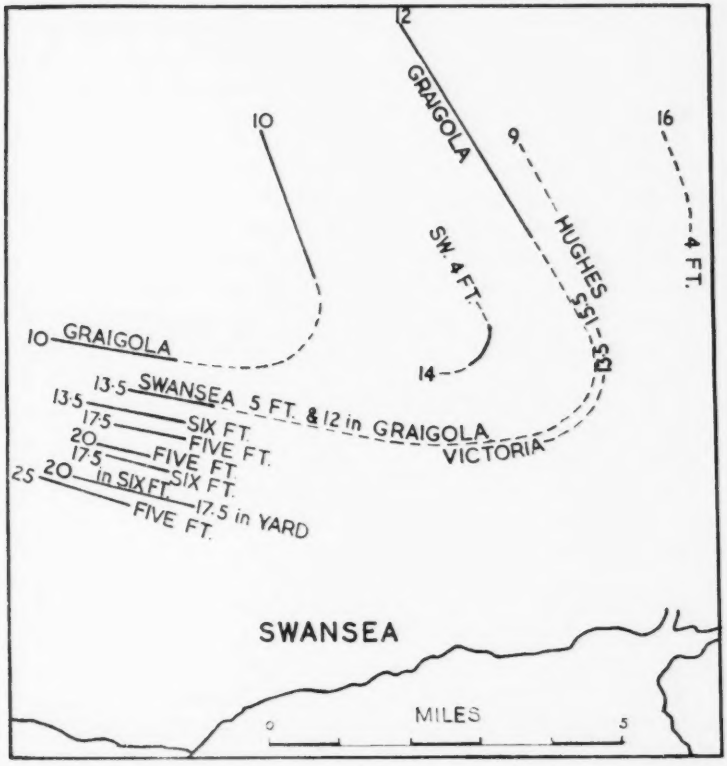
If, therefore, we assume that the reaction is controlled by some function such as porosity which decreases in more than linear ratio with depth, its product with a temperature function which increased in more than linear ratio with depth might be almost constant through a great range of depth until the effect of one or the other became predominant. This is illustrated in the following Table, in which it has been assumed for convenience that the temperature increases at the constant rate of 1° C. per 100 feet in depth, starting from a surface temperature of 20° C. The porosity has been calculated in accordance with Athy's relation between porosity and density in muddy sediments.

Depth, Feet	Pressure of Water Vapour in Bars	Calculated Porosity %	Product
2,000	·074	25	1·85
4,000	·199	9·9	1·97
6,000	·312	6·2	1·95
8,000	1·013	1·5	1·58
10,000	1·985	·6	1·21
12,000	3·614	·24	·87
18,000	15·552	·015	·23

The product of these two functions varies only as 1 to 8 over a range of depth of 16,000 feet and between 2,000 and 8,000 feet it varies only about 20 per cent. It is believed, therefore, that the combined effects of temperature and pressure functions which act in opposite directions, may largely explain the varying rates of devolatilization of coal, which in turn are reflected in the variation of Hilt rates from one part to another of a coalfield or from one coalfield to another. It is also necessary to take into account the rate of depression of the area which controls the rate of sedimentation in that area. It may be remarked, however, that whatever may be the exact mode of metamorphism of coal resulting from depth of burial, it certainly cannot be described as load metamorphism since it would be much more effective if, other conditions being present, the load were absent. With these simple assumptions it is possible to explain all the examples of greatly varying rates of devolatilization with depth which have been reported from British coalfields.

Brief reference may be made to two other regions in illustration of some of the difficulties encountered in interpreting varying Hilt rates.

The first region lies to the north-west of Swansea where three seams have been extensively worked ; these are in descending order : the Swansea Four-Foot, the Swansea Five-Foot, and the Swansea Six-Foot, widely known as the Graigola seam. The Coal Survey isovol



TEXT-FIG. 7.—Isovol map of coal seams north-west of Swansea. (Based on Coal Survey Isovol map.)

map shows certain isovols for these seams and some information regarding other near-by seams in the Pennant Sandstones (Text-fig. 7).

On the south side of a N.W.–S.E. axis of minimum volatile contents which, by the way, has nothing to do with the axis of a syncline which ranges in a wholly different direction a few miles to the north, the isovols in the Five-Foot and the Six-Foot seams pursue remarkably parallel courses, but the volatile percentages change very rapidly across their trend, while the average vertical distance between the two seams remains about 410 feet.

From the information available we find that at isovol 12 in the Six-Foot, the Hilt rate between the Five-Foot and the Six-Foot is 3 per

cent per 1,000, but farther south at isovol 25 on the Five-Foot the rate is 11·8 per cent per 1,000. The distance in which the Hilt rate is reduced to one-quarter is only just over a mile. It is obviously too hazardous to extrapolate these values to the surface as the depth range is too short. These relations along this portion of the south side of the coalfield recall, however, those in the Kent Coalfield between the axis and Bere Farm to the south. There seems to be no doubt that at one period in the history of the coalfield the thickness of the measures must have increased at a very rapid rate from the Gower peninsula where the rate of sedimentation was low towards the centre of the coalfield where as we have seen, the rate was probably high. The south-western part of the coalfield is almost certainly another example of the rule that where the measures were thin the Hilt rates were high and where they were thick the Hilt rates were low.

The other region is that of the Pie Rough bore in North Staffordshire, the coals of which were so carefully and systematically investigated by Millott, 1946. Within a depth of 4,210 feet from the surface samples from sixty-two horizons were analysed, both proximate and ultimate analyses being recorded. If one takes account of every layer separated by a foot to 3 feet only from the adjoining layer and gives equal weight to each, the result is unduly to favour a thick seam or what is almost the same thing, a series of several thin seams within a limited depth of strata. I have, therefore, averaged these analyses either into single horizons or assemblages of horizons separated by small depth intervals. The difference in treatment is not great but the grouping method gives a fairer representation of the changes of volatile content with depth.

It is quite evident as Millott reported that a uniform rate of change cannot be applied throughout the sequence. I therefore divided the vertical column which contains coal seams into three approximately equal depths, and calculated by least squares the Hilt rates for each depth range. Millott used two different methods of determining the volatile percentages ; these differ slightly but systematically from one another, the difference increasing on the whole with the volatile contents of the seams. The two methods cannot therefore lead to the same Hilt rates, which have been determined for each method separately.

The results are summarized in the following Table :—

	No. of Groups	Gas Method	V_0	Electric Furnace	V_0	Depth Range	Diff.
Upper Series, Nos. 1–21 .	12	3·23	46	5·4	50	728–1873	1145
Middle Series, Nos. 22–33 .	8	4·59	50	5·07	52	1873–3038	1165
Lower Series, Nos. 33–62 .	17	7·16	61	9·0	66	3038–4213	1173

As in other cases it is possible to explain these varying rates by a combination of the three factors, one due to temperature, the second an inhibitant—the pressure, and the third independent of both which is the rate of sedimentation. Thus, if we suppose that the chemical-physical factors remained unchanged the figures would suggest an acceleration of sedimentation at the surface, while the seams were near the finishing-off stage.

From the various examples which have been discussed it is obvious that *there is no simple mathematical law of devolatilization with depth which is applicable to any coalfield as a whole or even to different parts of one coalfield.* An arbitrary relationship can, however, be found for any coalfield, provided the Hilt rates and the volatile contents are known. The more numerous and the better distributed these are, the more that can be learnt regarding the geological history of a coalfield, the final depth to which any given coal seam was once buried below the surface and, knowing its present altitude, the amount by which that seam has been uplifted by subsequent movements.

In the South Wales Coalfield the measures thicken rapidly from east to west and the officers of the Geological Survey estimated that in the south-western part of the coalfield the measures were about 7,000 feet, which, even so, is less than half the final thickness of cover on the Nine-Foot seam suggested by the depth-of-burial theory. Consideration of a wider area suggests, however, that the Upper Carboniferous sedimentary column is far from complete in the South Wales Coalfield.

While normal sediments were deposited in South Wales in the zone of *Anthraconauta phillipsi* and *A. tenuis*, we find that in North Staffordshire the zone of *A. phillipsi* includes the red measures of the Etruria marl group about 1,000 feet thick. In the succeeding Newcastle group there was a partial return to the normal conditions, but the *A. tenuis* zone consists of the Keele group of red marls which may attain a thickness of 700 feet. The Keele beds are followed by the calcareous conglomerates and breccias of the Enville group which in Warwickshire attain a maximum thickness of 3,500 feet. Thus at their maximum these largely abnormal sediments amount to nearly 6,000 feet and suggest the types of deposits which may have occurred generally in the final stages of deposition of the Coal Measures before uplift put an end to the process. By comparison with the development of the Coal Measures on the Continent even the highest of these measures probably does not mark the upper limit of the Carboniferous period.

It is not unreasonable to suppose that the closing stages of sedimentation in the South Wales Coalfield were marked by somewhat similar changes and types of sediment as are recorded in the North Staffordshire and other Midland coalfields, and that a considerable thickness

of " continental " deposits was present at one time. There is, in fact, every reason to assume that the thickness of such deposits may have been substantially greater in South Wales than in the Midland region, by reason of the situation of this coal basin on the northern flank of the Armorican geosyncline. It is probable, however, that the deepest part of this geosyncline lay farther south in Devon and Cornwall, where the aggregate thickness of sedimentary rocks may well have considerably exceeded that in South Wales. As in Wales towards the close of the Lower Palaeozoic the deeper region of the Armorican geosyncline may have begun to rise while sedimentation was proceeding without much, if any, interruption on its northern flank. In such an event the products of denudation of the rising area would be swept forward to that flank to supply the final cover which buried to a great depth the coals of the coalfields.

It is unnecessary to point out that the courses of the isovols on an isovol map, with their maxima and minima and the varying distances between neighbouring isovols, resemble so much a series of structural contours drawn in a stratum affected by pitching folds that it is difficult to resist the impression that their distribution is in some way due to the post-Carboniferous earth movements which affected the field. One almost inevitably thinks of the minima as synclinal troughs and the maxima as anticlines. This impression is, however, false ; the isovols represent merely the distribution of the varying volatile contents of a given seam and according to the depth of burial theory this distribution is the same as when the seam lay in the earth at the end of the Coal Measures, before the onset of the Armorican earth movements which gave the field its existing structures of anticlines and synclines and various kinds of faults. The isobaths record the approximate amount of depression at various points of the Nine-Foot seam during the formation of the particular portion of the Armorican geosyncline now occupied by what remains after denudation of a much larger South Wales coalfield ; the troughs and ridges in the isobaths correspond therefore to maximum and minimum areas of depression.

Lines of progressive devolatilization must trend at right angles to the isovols and should therefore point towards these axes of isovol minima. Comparison of Dr. Trotter's fig. 1 with his isovol map, Text-fig. 8, demonstrates what a gross caricature of the facts is represented by the former figure in which the above lines are drawn as if they converged on the outcrop of the Careg Cennen Disturbance.

If, for the sake of argument, we assume that the original maximum cover over the Nine-Foot seam was 17,000 feet measured as fully compacted rock, the depth of the original column of mud and sand of varying degrees of compaction may well have been 20,000 feet. On any reasonable assumption regarding the temperature gradient during

the period of accumulation and the immediately following period when the geo-isotherms were rising throughout the geosyncline, it is difficult to suppose that the temperature of that seam could ever have exceeded 250° C.

According to some authorities anthracite can only be produced by a rise of temperature to over 500° C. This belief depends, however, on laboratory tests and it is almost certain that in the course of a long period of time comparable changes would be brought about at much lower temperatures. The history of the coals of the South Wales Coalfield seems to furnish conclusive evidence that this must indeed be the case.

Experimental researches (Cannon, etc., 1948) on various types of coal have recently shown that in bituminous coals there is a slight loss of volatiles between 100° and 200° although the main discharge occurs at about 400°, and it is clear that the curve of loss of volatiles against temperature has a perceptible slope at 100°. Even a slope of one-thousandth part of this would be ample to bring about in a long period of time the devolatilization noted in the various seam samples. The diagrams are too coarse to determine whether any comparable change occurs in anthracite.

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REFERENCES

British Regional Geology, South Wales. *Mem. Geol. Surv.*

—— Central England. *Mem. Geol. Surv.*

CANNON, C. G., GRIFFITHS, M., and HIRST, W., 1944. The Carbonisation of Coal *in* The Ultrafine Structure of Coals and Cokes. *The British Coal Utilization Research Association.*

DINES, H. G., 1933. The Sequence and Structure of the Kent Coalfield. *Geol. Surv. Summ.* Prog. for 1932, p. 15.

Handbook of Physical Constants, 1942. *Geol. Soc. Amer.*, Special Paper No. 36.

HICKLING, H. G. A., 1932. The Properties of Coals as determined by their Mode of Origin. *Journ. Inst. Fuel.*

ILLING, V. C., 1944. In discussion of papers by O. T. Jones and A. W. Skempton. *Quart. Journ. Geol. Soc.*, c, p. 158.

MILLOTT, J. O'N., 1946. The Seams encountered in a deep boring at Pie Rough, near Leek, Staffordshire. *Trans. Inst. Min. Eng.*, 105, 528.

POLLARD, A. W., and STRAHAN, A., 1908. The Coals of South Wales, 2nd ed., 1915. *Mem. Geol. Surv.*

RAISTRICK, A., and MARSHALL, C. E., 1939. The Nature and Origin of Coal and Coal Seams. *English Universities Press*, Ltd., London.

Regional Survey Reports, 1946. South Wales Coalfield. *Ministry of Fuel and Power.*

TROTTER, F. M., 1949. The Devolatilization of Coal Seams in South Wales. *Quart. Journ. Geol. Soc.*, civ (1948), 387.

WELLMAN, H. W., 1948. Metamorphic Gradients in the Kent Coalfield. *Econ. Geol.*, xliii, 506.

WHITE, D., 1908. Some problems of the formation of Coal. *Econ. Geol.*, iii, 292.

Geology of the Aust-Beachley District, Gloucestershire

By W. F. Whittard

(PLATES XX–XXII)

Abstract

The folds and many of the faults in the Keuper Marls of the Aust-Beachley District are claimed to be compaction phenomena. The distribution of almost vertical sheets of alabaster in the Keuper Marls is attributed to infilling of contraction cracks. The palaeontology of the Carboniferous rocks, particularly of the seldom-visited islands of the Severn, is used to determine the structure. Several post-Triassic faults of tectonic origin have been mapped and others predicted; the age of the faulting is unknown.

Introduction

THE Roman city of Glevum, of which the City of Gloucester is the modern descendant, was sited alongside the lowest fordable crossing of the River Severn. The Severn Estuary commences below this position and shows so rapid an increase in breadth that throughout the ages it has constituted a major obstacle to land traffic. Even to-day no road crosses the estuary, the only communications between either bank being by the Severn Railway Tunnel, the Sharpness Railway Bridge, and the Aust–Beachley Ferry.[1] The ferry plies where the river attains the maximum range of spring tides of 41 feet [2]; the flow of road traffic may be retarded by the ferry and, owing either to a low or to an exceptionally high tide or to limited berth facilities, motorists occasionally have to make a detour of approximately 55 miles via Gloucester in order to travel between South Wales and the southern and south-western counties of England. A road-crossing of the river at the most convenient position, namely between Beachley and Aust, is claimed by many to be a national need.

The first plan envisaged two road tunnels each carrying a one-way stream of traffic. Adequate information of the geology of the area, however, was not available, particularly of the five islands lying offshore from Aust Rock which are exposed only at low tide; the most recent data relating to the rocks between English Stones and Oldbury Sands are contained in two confidential reports, of which

[1] The limits of the estuary are difficult to define but the pilotage areas for the Bristol Channel and the Severn Estuary are considered navigationally to join at King Road, Avonmouth. Physiographically the argument could be made that the estuary extends from Gloucester as far as a line drawn from Morte Point to Worms Head, a distance of 117 miles as measured along the river.

[2] Bassindale, R., 1943. Studies on the Biology of the Bristol Channel. XI. The Physical Environment and Intertidal Fauna of the Southern Shores of the Bristol Channel and Severn Estuary. *Journ. Ecology*, xxxi, pp. 6 and 7.

a condensed account was published in 1933.[1] A geological map on the scale of 25 inches to one mile was therefore made with a view to determining the geological difficulties likely to be encountered in tunnelling. For reasons mainly non-geological, an alternative plan was formulated for a suspension bridge carrying a central span of 3,300 feet; the geological problems under this new scheme are associated with foundation rocks, and a programme of borehole drilling has now been completed.[2]

Acknowledgment is rendered to Dr. Stanley Smith, who named the fossils collected from the Carboniferous Limestone. I also acknowledge a grant towards the cost of publication of this paper received from the Colston Society.

The Mesozoic Rocks

The classical section of Triassic-Rhaetic-Liassic strata of Aust Cliff has been the subject of several authoritative accounts, the first of which was written in 1824 by Buckland and Conybeare [3] and the last in 1946 by Reynolds,[4] but some of the familiar structures are re-interpreted here, and new information is made available.

The dominant structure is a gentle anticline crossing the cliff 200 feet north-east of Aust Head (Plate XX, A). To the south the strata are traversed by several faults all of which possess a downthrow never exceeding 20 feet away from the anticlinal axis. To the north-east three subsidiary synclines and two additional anticlines possess amplitudes of from 3 to 4½ feet measured at the base of the cliff, but they are supratenuous folds dying out upwards; no more than one fault is visible and this downthrows westwards. The folding and faulting have been tacitly attributed to tectonics but they can more readily be explained by compaction of the Keuper Marls. The Carboniferous Limestone forms an almost flat-topped ridge at Aust Rock, plunging steeply to north and south, and over which the Triassic beds unconformably rest. The ridge was succeeded above by a less thickness of deposits of Keuper age than was developed to the north and south, because in those directions the Triassic landscape occurred at a lower level and received a greater thickness of sediment. As a sequel to compaction there would be less reduction in thickness above the ridge as compared with that above the flanks, and an anticlinal flexure would develop. The bending moment induced by the increasing amounts of thickness-reduction of the marls when traced

[1] Report Severn Barrage Committee. *H.M. Stationery Office Publication* No. 63–78–1, pp. 16–19, 1933.

[2] Whittard, W. F., 1948. Temporary Exposures and Borehole Records in the Bristol Area. I. Records of Boreholes sunk for the New Severn and Wye Bridges. *Proc. Bristol Nat. Soc.*, xxvii, pp. 311–328.

[3] *Trans. Geol. Soc.*, 2nd Ser., i, p. 304 (pl. 37), 1824.

[4] *Proc. Cotteswold Naturalists' F.C.*, xxix, pp. 29–39, 1946.

southwards away from the ridge is proposed as the cause of the small-scale faulting exhibited in the cliff. However, a difficulty arises when a date for the completion of most of the compaction is considered ; if compaction had been almost fully effected before the Jurassic deposition occurred, the fact that the faults cut the Lias would seem to prove the attribution of faulting to a bending moment developed out of compaction to be incorrect. Neither the folds nor the faults have any effect on the underlying Carboniferous Limestone and they are clearly peculiar to the Keuper Marls ; a tectonic explanation is thus improbable.

The planed off surface of the ridge of Carboniferous Limestone on Aust Rock is assumed to have been produced during Trias times, but the evenness is broken by a north-westerly directed valley now infilled by Dolomitic Conglomerate and Keuper Marl (Plate XX, B). The complexity of the ancient land surface is also suggested by the logs of the boreholes sunk at the foot of and behind Aust Cliff which prove the surface of the Carboniferous to descend rapidly south-eastwards and possibly to occupy a continuation of the valley identified on the foreshore.[1] Carboniferous rocks reappear at Blackstone, north-east of Aust Rock, the intervening ground being occupied by Keuper Marls infilling a depression which faces the minor anticlines and synclines and the single fault already described from the north-eastern portion of the cliff section. These minor topographical irregularities of the Trias land surface may modify in detail the folding and faulting of the Mesozoic strata, but individually they are not considered to play an important role in determining the main structures in the cliff which, as already stated, are claimed to arise out of differential compaction, particularly of the Keuper Marls.

Another expression of the compaction which the marls have experienced is shown in the synclinal structures associated with infilled valleys, as developed on the foreshore between Beachley Point and the Hen and Chickens, and also at Aust Rock (Plate XX, B). The Trias unconformity can be accurately mapped in both areas and, without exception, the dips of the Dolomitic Conglomerate and the marls are away from the ancient land surfaces towards the valley bottoms. The curving strike in the Trias strata is sympathetic with the sinuous form of the unconformity and the valley infillings show a synclinal structure, which is evidently not due to tectonics. Greater sedimentation in the valleys than on their flanks would produce greater compaction and a synclinal form would emerge, although this may have been initiated by a depositional inclination. The large-scale map (Text-fig. 1) of Beachley Point exhibits the swinging strike, the variable

[1] Whittard, W. F., op. cit., p. 315.

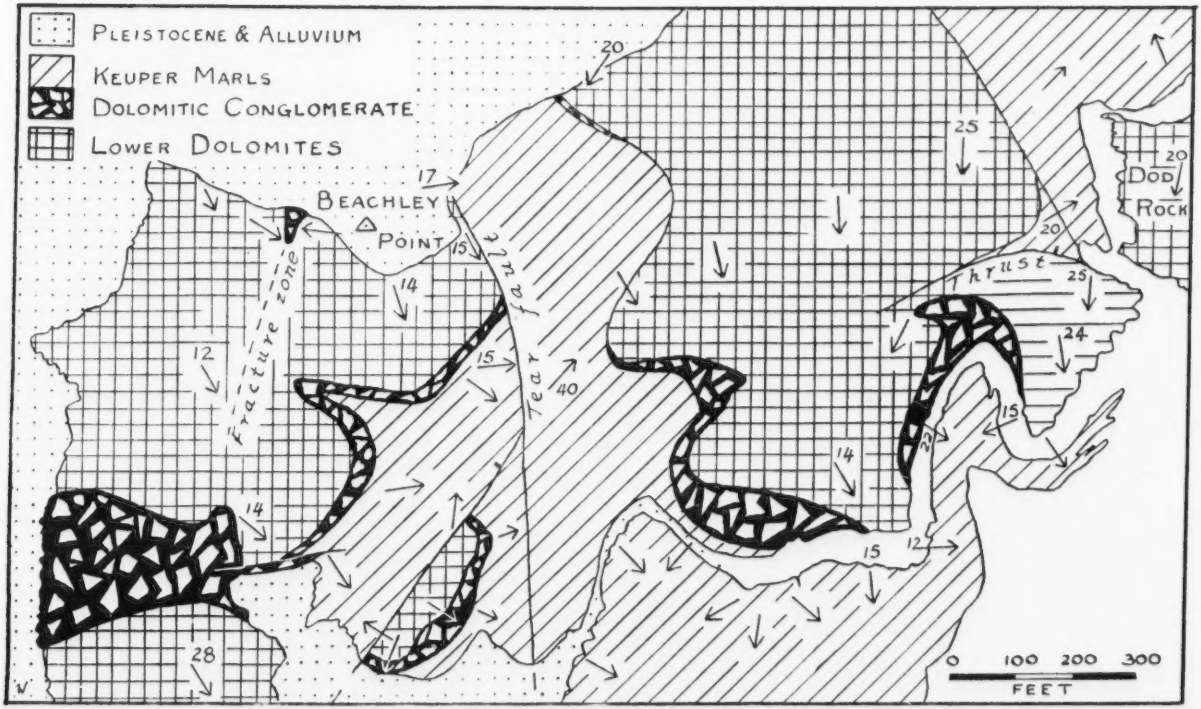
direction of dip, the high angles of dip relative to that prevailing generally in the Keuper Marls and the synclinal structures ; similar information, but with less detail, is shown on the smaller scale map of Aust Rock and of the country immediately north of Beachley Pier (Plate XXII).

A zone of gypsiferous marl is exposed in the cliff on both sides of Aust Head, but particularly on the south side, and is developed towards the base of the Keuper Marls. The gypsum occurs in the form of alabaster and satin spar, the latter being considered as secondary in origin. A typical section (Plate XXI, A) of the gypsiferous zone is appended.

	ft.	*in.*
(*g*) Red marls		
(*f*) Satin spar	0	1
(*e*) Red marls with curvilinear vertical sheets of alabaster and horizontally disposed wisps of satin spar . . .	7	0
(*d*) Red marls with thin layers and wisps of satin spar, and towards the base a concentration of nodular alabaster accompanied by stringers of satin spar . . .	3	0
(*c*) Red marls with curvilinear vertical sheets of alabaster and horizontal wisps of satin spar	3	0
(*b*) Nodular alabaster and satin spar included in red marls .	4	0
(*a*) Red marls		

No example was seen where a vertical sheet of alabaster of the lower bed *c* transgressed the intervening bed *d* to the upper bed *e*, although veins of satin spar occasionally do so. The sheets of alabaster, so common in beds *c* and *e*, possess a significant distribution. At first sight they appear to occupy random directions, but when plotted there are five or six predominant trends, and obviously the alabaster occupies fissures which fundamentally are polygonal in design, but with curved sides ; this arrangement can occasionally be seen in plan (Plate XXI, B). The two beds of marl containing the sheets of alabaster exhibit the features of contraction cracks occasioned by the partial drying out of mud, much as cracks are induced in the modern sun-dried muds of the Severn Estuary. The sheets are not infrequently discontinuous, a condition to be expected where cracks had coalesced or had become infilled with mud before the saline waters which flooded them were sufficiently concentrated to deposit the alabaster.

Specimens of so-called salt pseudomorphs are distributed throughout the shingle at Aust Head and are sometimes found in place at that locality and at the north-eastern end of Aust Cliff, but the term is a misnomer. Apart from the mineralogical difficulties of chemically replacing rock salt by micaceous marl and siltstone, wherever found in place in the field the " pseudomorphs " always occur on the underside of the siltstone and are the casts of moulds of salt crystals. The development by solution of the moulds may have occurred before the succeeding sediment was deposited, but solution could also have



TEXT-FIG. 1.—Intertidal outcrops from Beachley Point to Dod Rock.

(*Note*.—The area shaded with horizontal lines south-west of Dod Rock and south of the thrust should be shaded with crossed lines indicating Lower Dolomites.)

happened when sedimentation was in progress. The crystallization of the salt ensued when most of the mother liquor was evaporated, and the additional evidence of contraction cracks in the marls also indicates that the waters in which the marls were laid down retreated and permitted the development of land surfaces, if only for short intervals of time.

The Carboniferous Rocks

At Chepstow the Geological Survey has determined the succession of which that portion given below is pertinent to the Aust–Beachley district :—

Carboniferous Limestone (lower part only)	Lower Dolomites (Z-C_1 zones)		320 feet
	Lower Limestone Shales (K zone)	Shales with thin Limestones	160 feet
		Lower Limestone	50 feet

In the Aust–Beachley district the Lower Limestone comprises dolomitic, platy limestones, red, yellow, or grey in colour, and occasionally interbedded thin, calcareous, greyish-mauve shales. The shales with thin limestones have not been recognized at the surface anywhere in the area but have been proved in bore-holes on the foreshore at Beachley. The Lower Dolomites are fine-grained, compact, tough, dolomitic limestones, often grey in colour but maroon and dark grey beds commonly occur.

The stratigraphical and palaeontological details are best considered by taking the isolated Carboniferous outcrops, commencing with Blackstone at the northern end of the Aust section.

Blackstone.

The western end of Blackstone alone could be reached, but here thin-bedded, closely jointed, mineralized, yellowish-brown and red, dolomitized limestones are interbedded with thin, calcareous, greyish-mauve shales. The fauna contains *Schellwienella* sp., *Camarotoechia mitcheldeanensis* Vaughan, *Syringothyris* cf. *cuspidata* (Martin), *Protoschizodus* sp., *Myalina* sp., *Edmonsia* sp., and dwarf gastropods ; it is an unusual assemblage but the rocks certainly belong to the K zone, and the abundance of lamellibranchs and gastropods at once suggests a correlation with the Lower Limestone.

Aust Rock.

The weed-covered surface of the ground, exposed about half ebb, is gently inclined south-westwards, and is an erosion platform of Trias age. Small outliers of Dolomitic Conglomerate rest upon it. The

Trias-filled north-westerly trending valley has already been mentioned (p. 367) ; the steep west side of the platform is flanked by Dolomitic Conglomerate inclined at angles up to 18°, and between Little Ulverstone and Aust Rock there is a Trias valley which to-day contains a remnant of Trias strata.

The majority of the surface of Aust Rock is composed of limestones providing numerous, yellow-stained, crinoid ossicles. The best collecting localities are in the spur facing Little Ulverstone ; the fauna correlates with the Lower Dolomites and includes *Zaphrentis omaliusi* E. & H., *Koninckophyllum praecursor* Howell, *Rhipidomella michelini* (l'Eveille), *Plichochonetes* cf. *hardrensis* (Phillips), *Schellwienella crenistria* (Phillips), *Leptaena analoga* (Phillips), *Spirifer tornacensis* de Koninck, and ? *Tylothyris laminosa* (McCoy).

Selecting an average dip of 20° and assuming no repetition by strike faulting, 450 feet of Lower Dolomites are exposed on Aust Rock. This figure is a third more than the total thickness for the Lower Dolomites at Chepstow ; furthermore, zones of brecciation trending approximately parallel to the strike can be detected and the limestones are extensively jointed. It is also significant that a fauna with *Koninckophyllum praecursor* was collected near the north-west point of Aust Rock ; this coral is suggestive of a C_1 rather than a Z_2 age, but the stratigraphical position of the rocks would be Z_2 if the succession were normal. The outcrop of the Lower Dolomites is claimed to be complicated by strike faults of unknown extent resulting in an excessive thickness of outcrop.

Little Ulverstone.

The eastern and south-western edge of the island is flanked by coarse-grained Dolomitic Conglomerate, and at low water of the spring tide the saddle between the island and Aust Rock is seen to be made of a similar rock. A Trias valley was developed between Little Ulverstone and Aust Rock, and there is evidence to claim another such valley between Little and Great Ulverstone.

Grey, yellow-speckled, dolomitic limestone constitutes most of the island. The fauna points to a correlation with the Lower Dolomites (possibly Z_2) and includes *Phillipsia scabra* Woodward, *Zaphrentis* (*Zaphrentoides*) *koninckii* E. & H., *Rhipidomella michelini*, *Plichochonetes* cf. *hardrensis*, *Leptaena analoga*, *Schellwienella* cf. *crenistria*, *Productus* (*Pustula*) *subpustulosus* Thomas, *Productus* ? *vaughani* Muir-Wood, *Cleiothyridina* cf. *glabristria* (Phillips), *Spirifer tornacensis*, and *Tylothyris laminosa*. The *Koninckophyllum* fauna from Aust Rock was collected from what appeared to be the same bed on Little Ulverstone, but that from Aust Rock proved to be much the younger ; a fault is postulated between the island and the mainland and the

Trias valley which passes between them may have been eroded along this fault plane.

Great Ulverstone.

Apart from the Dolomitic Conglomerate which bounds the eastern margin, grey and pink, crinoidal, dolomitic limestone comprises most of the island. Few fossils were discovered but a recent borehole has produced a fauna suggesting a Z_2 age ; the rocks are to be placed in the Lower Dolomites.[1] The limestones are crossed by a north-westerly trending fracture zone, of which there is a difference of 35° in dip direction between the two sides.

Leary Rock.

The island, which consists of red, yellow and grey, platy, crinoidal, dolomitic limestones, is divided longitudinally at half ebb and the two portions may be separated by a fault zone ; the state of the tide was such that this could not be proved, but there is a difference in dip direction on the two sides. The meagre fauna contains *Plichochonetes* cf. *hardrensis*, *Schelwienella* cf. *crenistria*, *Camarotoechia mitcheldeanensis* and spiriferids, and the lithological types, including a red limestone charged with white crinoid ossicles and a bryozoa limestone, indicate the presence of the Lower Limestone (K zone). Assuming no repetition due to faulting and an average dip of 15°, approximately 65 feet of the Lower Limestone are exposed.

Upper Bench.

Dull pink, dolomitic, crinoidal limestones alone were seen in the short visit permitted by the tides. The rocks belong to the Lower Dolomites and the fauna is consistent with a C_1 rather than a Z_2 age, but reliable diagnostic fossils were not obtained. The fossils recovered included *Pleurodictyum* (*Michelinia*) *favosa* (Goldfuss), *Plichochonetes hardrensis*, *Schellwienella* sp., *Camarotoechia mitcheldeanensis*, *Cleiothyridina* cf. *glabristria*, *Spirifer tornacensis*, and *Tylothyris laminosa*.

Since Leary Rock is formed of the Lower Limestone (K zone) and the Upper Bench of the Lower Dolomites (C_1 zone ?), the shales and thin limestones which in the normal succession occupy an intermediate position, might be expected to occur in the river bed between the two islands. If an average dip of 15° be assumed there is room for a maximum of 200 feet of shales with thin limestone. This figure is probably excessive, it exceeds the 160 feet determined for these rocks at Chepstow, because the lowest beds of the Lower Dolomites have presumably to be included in that thickness. It may be concluded that apart from slight disturbances possibly in the shales with thin limestone the succession from Leary Rock to the Upper Bench is moderately

[1] Whittard, W. F., op. cit., p. 317, borehole 14.

straightforward. The existence of a trough between the islands is shown on Admiralty Charts and supports the view that the shales with thin limestones are developed and have been extensively eroded along their strike mainly by the ebb flow which is diverted by the Hen and Chickens across the river from the west bank.

Lower Bench.

The island, exposed for a short time only at low tide, consists of dolomitic limestones ; fossils are scanty but include *Syringopora* forma *distans* and *Koninckophyllum praecursor*, and indicate possibly a C_1 age.

There is a similar difference in the direction of dip between the rocks of the Upper and Lower Bench as prevails between the north and south parts of Great Ulverstone, and a continuation of the fault zone on the latter island may pass between the two islands.

North of Beachley Pier.

The Keuper Marls show several layers of sandstone and also contain numerous nodules of gypsum. The Dolomitic Conglomerate is massive and may carry angular limestone blocks attaining a length of 18 inches ; the outcrop is sinuous and, in a measure, reflects the distribution of the Carboniferous and Old Red Sandstone rocks to which it constitutes a discontinuous mantle.

The Carboniferous is represented in three inliers (inset, Plate XXII) in which the rocks exhibit considerable variation and include massive false-bedded green and pink sandstones, thinner-bedded greyish-white and pinkish-yellow sandstones, and crinoidal red limestones. The sparse fauna includes *Plichochonetes hardrensis*, *Camarotoechia mitcheldeanensis* and common fenestellids and points to a correlation with the Lower Limestone (K zone). The abundance of sandstones is suggestive of the lowest part of the Lower Limestone ; the strata may appertain to the passage beds between the Carboniferous and the Old Red Sandstone, and this view is supported by the close proximity of the Old Red Sandstone outcrops alongside the Lyde Light and at the Hen and Chickens. Here massive light grey, brown and green sandstones, brown conglomeratic sandstones with vein-quartz pebbles, and fissile highly micaceous brown sandstones are exposed and may be included in the Tintern Sandstone Group.

Beachley Point to Beachley Pier.

The rock-sequence on the Beachley foreshore is complicated by faulting affecting Carboniferous and Triassic strata (Text-fig. 1). The Lower Dolomites show their usual lithology and in the cliffs at the western end of Beachley Point and at about the level of high tide *Zaphrentis* (*Zaphrentoides*) *koninckі*, *Z. omaliusi*, *Z. delanouei* E. & H., an early stage of *Michelinia*, and *Spirifer tornacensis* were obtained ;

Z. koninckí is the commonest form and the assemblage is characteristically of Z_2 age. The Lower Limestone Shales do not crop out on the foreshore but the rocks have been proved in boreholes 5, 20, and 21 which were sited short distances south-west of Beachley Pier.[1]

Beachley Plateau.

The cliffs defining the Beachley promontory rise steeply to an almost level surface standing between 50–60 feet above Ordnance Datum. The surface of the plateau is occupied by Pleistocene sands and gravels which attain a maximum thickness of 23 feet as proved by boreholes. Trias rocks were penetrated below the Pleistocene veneer and in all cases the Lower Dolomites were reached. The only exposures of Lower Dolomites are in the vicinity of Ewen's Rock at the north-west corner of the plateau and *Zaphrentis* (*Zaphrentoides*) *koninckí*, *Z. omaliusi*, and *Syringopora reticulata* Goldfuss are indicative of a Z_2 age.

Geological Structure

The faults and folds visible in the Mesozoic rocks of Aust Cliff have already been attributed mainly to non-tectonic causes, and the excessive thickness of Lower Dolomites on Aust Rock has been used as an argument for the development here of strike faulting of unknown extent.

The thicknesses of the subdivisions of the Carboniferous for the islands in the River Severn is inconsistent with and greatly in excess of the figures available for the Chepstow District, notwithstanding a reasonable allowance for variations in thickness between the two regions.

The distance between Blackstone and the nearest point on Aust Rock is such that a thickness of the order of 300 feet or 400 feet, according as an average dip of 15° or 20° be adopted, is required for the shales with thin limestones of the K zone. The thickness at Chepstow is unlikely to become doubled at Aust, and folding or strike faulting, probably the latter, may account for the apparent increase.

A south-south-east fault passing to the west of the Hen and Chickens has been mapped ; what is the likelihood of a fault with a comparable direction being developed on the east of the Hen and Chickens ? If the strike of the Lower Limestone of Leary Rock is continued towards the Old Red Sandstone of the Hen and Chickens, and soundings in the river suggest that an extension does occur, rocks of different ages would come into apposition. A sharp southerly curvature in strike is demanded in order that the Lower Limestone of Leary Rock succeeds normally the Old Red Sandstone. If this were the case, the dip of the Old Red Sandstone would almost certainly possess a southerly or a south-south-easterly direction, whereas it is inclined

[1] Whittard, W. F., op. cit., pp. 318–321.

consistently S. 35° W. A fault is thought to be present to the east of the Hen and Chickens, and may coalesce with the known fault immediately to the west, so as to run in a depression detected on the river bed, and to continue between the Lower and Upper Bench, where it would also account for the anomalous behaviour in the dip directions of those islands and for the increase in thickness in the Lower Dolomites which otherwise is developed there.

The deep trough in the river bed charted between the Upper and Lower Bench on one side and Great and Little Ulverstone on the other may have no tectonic significance. A minimum thickness of 410 feet for the Lower Dolomites can be calculated if the succession including Upper Bench and the northern part of Great Ulverstone as far south as the fracture zone traversing that island is considered simple ; this thickness is in excess of the measurements made at Chepstow. A difference in direction of dip can be detected on Leary Rock and Blackstone, and in the absence of faulting a curving strike is required in order stratigraphically to connect the two islands. Some geological anomalies are thus associated with this trough, and the possibility that it is partly controlled by a zone of fracture should not be lightly dismissed.

The folding in the Keuper Marl on the foreshore at Beachley is attributed to compaction, but the faults are definitely tectonic in origin. The area has been affected by at least two different periods of movement, one earlier and the other later than the Trias.

Pre-Triassic movements are indicated by innumerable joints in the Lower Dolomites, many of which are now infilled with Dolomitic Conglomerate, and by a zone of brecciation trending north-north-eastwards and occurring 80 yards west-north-west of the Trigonometrical Station on Beachley Point ; here, a small valley eroded along the zone of disturbance is also occupied by Dolomitic Conglomerate.

Post-Triassic movements are exemplified in the westerly-hading tear fault exposed to the east of Beachley Point where Lower Dolomites overlie Keuper Marls, in the thrust fault south-west of the Dod Rock where Lower Dolomites have advanced from the south-east over Trias and Carboniferous strata, in the vertical fault which trends south-eastwards to the Severn near Dod Rock and in the opposite direction probably joins the Beachley Point tear fault, and in the fault which parallels the shore from the Hen and Chickens north-westwards. The relationships of the Lower Limestone Shales (*vide* boreholes 5, 20, and 21) to the Lower Dolomites of the Old Limekiln and Dod Rock to the south, and to the Carboniferous and Old Red Sandstone north of the pier cannot yet be determined, because the mantle of Keuper Marls effectively obliterates most of the Palaeozoic rocks, but the succession is presumably abnormal.

Within the Aust–Beachley area the effects of tectonic movements of post-Triassic age, possibly posthumous in kind, are mainly confined to the Monmouthshire side of the Severn. Although a Miocene age might be claimed for them there is no evidence within the area which precisely dates the period of the movements. A pre-Upper Jurassic time is not altogether inadmissible ; the presence of faults and the absence of tectonic folds is inconsistent with the magnitude of the load of superincumbent strata, which surely would have been involved if the movements were of Miocene date.

EXPLANATION OF PLATES

PLATE XX

A.—Anticline, attributed to compaction, developed in the Keuper Marls 200 yards north-east of Aust Head. The photograph was taken from the Carboniferous Limestone platform at the south-east corner of Aust Rock looking south-south-east along the crest of the fold in the marls.

The foreground, as far as the isolated patch of shingle, is formed of Carboniferous Limestone, but the weed-covered rocks on either side and beyond this shingle belong to the Keuper Marls ; they show anticlinal dips consistent with the anticline shown in the cliff.

The light zone near the top of the cliff indicates the Tea Green Marls, while at about one-third the distance up the cliff can be detected the gypsiferous marls containing nearly vertical sheets of alabaster.

B.—The platform of Aust Rock as seen to the north-west from the top of Aust Cliff. The Carboniferous Limestone, covered with sea-weed, shows a series of dip slopes inclined to the south-west which are crossed by joints. The north-westerly orientated Trias valley is indicated by the tongue of water of which the limits approximately coincide with the Trias-Carboniferous unconformity. The synclinal form and the swinging strike of the Trias are indicated by the sinuous ridges just emerged from the receding tide.

The patch of shingle at the bottom right hand half of the picture is the same as the patch referred to in the description of the previous photograph.

PLATE XXI

A.—Gypsiferous beds exposed in the Keuper Marls 100 yards south of Aust Head (for details of succession see p. 368). *b* and *d* carry nodular alabaster, and *c* and *e* the nearly vertical sheets of alabaster which are claimed to occupy cracks formed in sun-dried muds. The sheets are variously disposed, the broad expanses indicating an orientation almost parallel with the plane of the photograph.

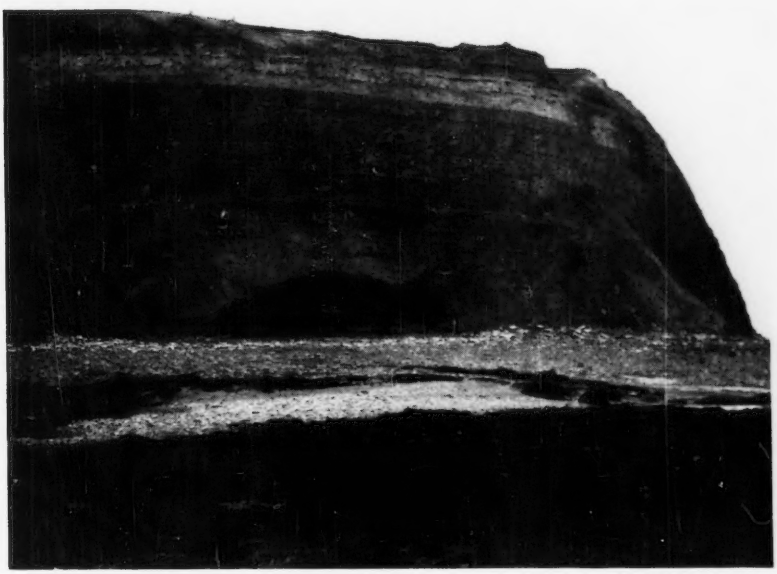
The white streaks are formed of satin spar.

B.—An oblique photograph of part of a nearly horizontal platform protruding from underneath bed *d*, and exposed about 50 yards south of previous locality. The polygonal pattern of the alabaster sheets is discernible.

PLATE XXII

Geological map of the Aust-Beachley area on the scale of 4 inches to 1 mile. A : anticline. S : syncline. The inset is a larger scale map of the area immediately north-west of the Hen and Chickens, and shows the three inliers of Lower Limestone. A larger scale map of the area south and east of Beachley Point is shown in Text-fig. 1.

A

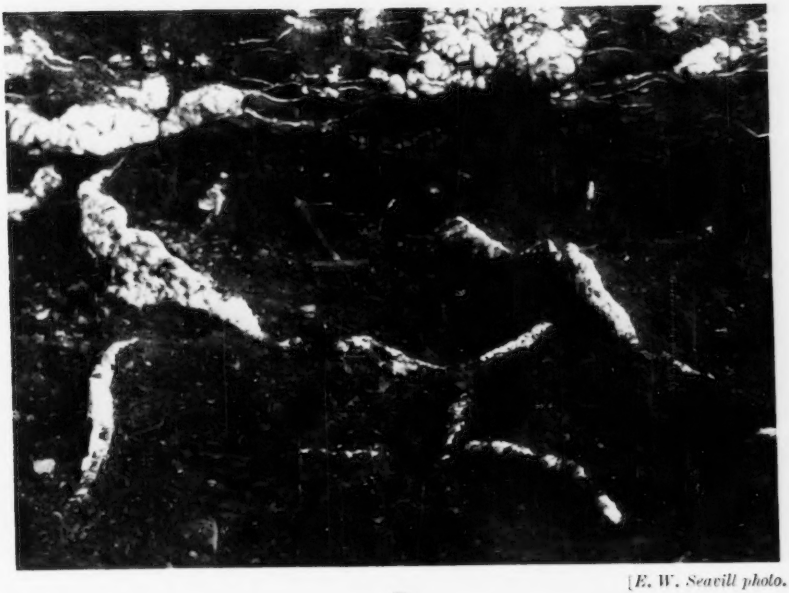


[*E. W. Seavill photo.*

B

AUST ROCK AND CLIFF.

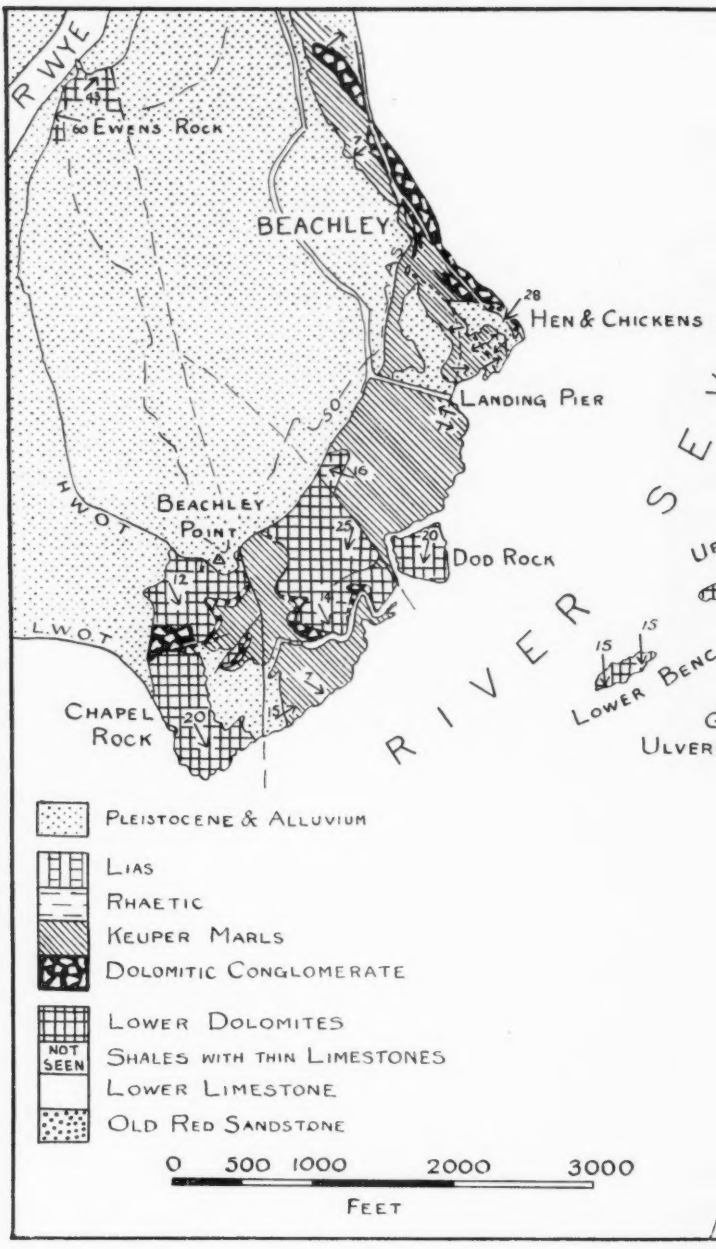
A



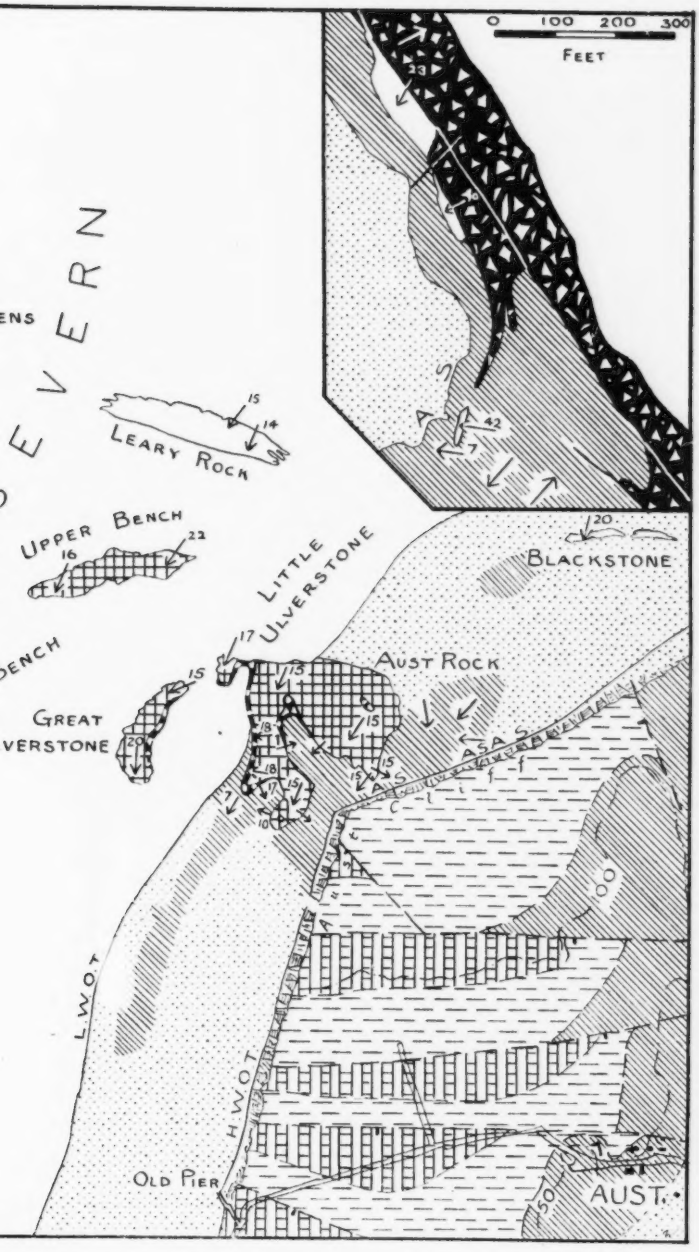
[*E. W. Seavill photo.*

B

KEUPER MARLS OF AUST CLIFF.



GEOLOGICAL MAP OF THE AUST-BEA



BEACHLEY AREA, GLOUCESTERSHIRE.

The Lizard-Start Problem

By J. B. Scrivenor

Abstract

Two questions are discussed : what is the nature of the boundary between the Devonian rocks of the Meneage and of the Start area on the one hand, and the mica- and green schists to the south of them on the other ; and are the latter also Devonian or older than Devonian ? The author gives his views on the boundary in both cases, and concludes that the mica- and green schists in both are of Devonian age.

THE publication of the revised edition of the Geological Survey memoir on the Lizard and Meneage (1946), after a long delay owing to the war, affords an opportunity for reviewing the problem of the nature of the boundary between the Devonian rocks of the Meneage in Cornwall and of the Kingsbridge area in South Devon on the one hand, and the mica-schists with green schists south of the boundary in both areas on the other. It is generally agreed that the mica-schists in both areas are closely related, but two sharply conflicting views of their age have been expressed ; one that they are Devonian rocks more altered than those to the north ; the other that they are very much older than Devonian, perhaps Archaean. It is not necessary here to give a summary of all the previous literature on this subject as that has been done in the Geological Survey memoirs to the dates of publication (*supra*, and 1904 for the Kingsbridge and Salcombe country), but there are a few other publications to be mentioned. In Cornwall, Dr. Eileen M. Lind Hendriks has done much valuable work (1937 and 1939) including a discussion on the Start-Dodman-Lizard Boundary Zone. In 1923 Professor C. E. Tilley discussed the metamorphosed rocks of the Start area and in 1938 published a further paper on the green schists found there. It should be noted that the term " Start area " has been used for the South Devon promontory that extends from Bolt Tail to Start Point and contains the Salcombe Estuary. It has the advantage of brevity. In 1938 and 1939 five contributions to the geology of the Lizard were published by me. These appeared after the late Sir John Flett had written his revised memoir, but in 1938 I had the advantage of discussing both areas with Sir John, Dr. Hendriks, and Professor Tilley so fully that there is nothing in this paper that I have not communicated to them either verbally or in letters.

The Lizard

In the first edition of the memoir on the Lizard and Meneage (1912) the nature of the boundary between the crystalline rocks of the Lizard and those to the north was left an open question ; but in the revised version Sir John decided in favour of a faulted and thrust boundary and a pre-Cambrian or Archaean age for the Old Lizard Head Series

of mica-schists and associated green schists. He said : " The balance of evidence is entirely in favour of the pre-Cambrian or Archaean age of the sedimentary rocks of the Old Lizard Head Series and of the period of their metamorphism and of the intrusion of the Man of War gneiss. These rocks are part of a vanished land of crystalline schists and gneisses that in all probability had a considerable extension to the south and south-west. The crystalline schists of the Start in Devonshire and the gneiss of the Eddystone are probably members of the same series " (1946, map on p. 151, and text p. 118). My views on these points, namely that although dislocations occur on either coast of the Lizard, none has been proved to be a boundary-fault or boundary-thrust, and that the Old Lizard Head Series is Devonian metamorphosed in a different manner and degree compared with the Devonian beds on the north, have been sufficiently stressed already. I have nothing to alter in my published contributions.

Dr. Hendriks (1937), by unravelling the structure of a very complicated district to the north and north-east of the Lizard, rendered a signal service to those who for many years had been puzzled by the stratigraphy of South Cornwall. I have seen much of the ground she has described and appreciate the difficulties with which she had to contend. Her principal conclusions (1937) were that beds previously mapped as " Grampound ", " Ladock ", " Menaccan ", " Falmouth ", " Portscatho ", and part of those mapped as " Veryan " are really a continuous suite to be named " Gramscatho Beds " resting on Lower Devonian (Meadfoot) strata. The quartzites of Veryan with Ordovician fossils and fragments of limestone with Silurian fossils owe their position to thrusts with younger beds below them. The lateral movement which produced tectonic breccias was contemporaneous with an intrusion of serpentine like that of the Lizard and this intrusion and the pre-existing rocks can be correlated with the serpentines and hornblende-schists of the Variscan folds in the Lower Carboniferous province of central Europe. Her paper was accompanied by a map (pl. xxii) and sections (pl. xxiii). In the former, two lines representing crush-belts are shown crossing from the land north of Dodman Point to the Start area, the northern one with a query, the southern coinciding with the junction between the Devonian rocks of South Devon and the mica- and green schists. In one of the sections (pl. xxiii, fig. 3) the Lizard Boundary is shown as a " crush-belt (Great Thrust) ".

In 1939 Dr. C. J. Stubblefield published a paper on fossils that had been found within the limits of the 1 in. sheet 359 (Lizard and Meneage). He disagreed with the Silurian age attributed to black shales in Fletching's Cove and slate at Nare Cove, regarding them as Devonian. He also disagreed with the Ordovician age attributed to silt-stone at Mudgeon. He was unable to trace an *Orthis* found by J. H. Collins

in 1879, and said (op. cit., p. 64) : " despite repeated searches in the various quartzite outcrops of the Crush Zone and in the dry-stone walls of the neighbouring country there has been neither confirmation nor repetition of the earlier finds." An *Orthis* found at Mudgeon was re-determined as *Chonetes*, and the author concluded, after more fossils had been collected, that the rock was Lower Devonian. Other fossils found in black shale at Carn near Manaccan, were also regarded as Lower Devonian. This paper, however, did not deal with the fossils outside sheet 359 and mentioned by Dr. Hendriks (1937, pp. 332–4) as Ordovician and Silurian, except that a new genus *Corineorthis*, and species *C. decipiens*, are described from Perhaver, Goran Haven, the geological range being given as : " Probably Middle Ordovician, but horizon uncertain."

In the same year (1939) Dr. Hendriks discussed the nature of the boundary, being of the opinion that it is a zone rather than a line. She ascribed the inclusion of blocks of Ordovician and Silurian rocks in Devonian strata to nappe movements : " The boundary-zone is defined as a belt of variolite (ophiolite) " (spilite J.B.S.), " exotic blocks and serpentine intrusive in, and contemporaneous with, a great thrust. . . . The evidence appears sufficient basis for the suggestion that the Start–Dodman–Lizard boundary-zone may be a relic of a great Variscan nappe, associated with the fan-structure of Cornwall (loc. cit., p. 401)."

Before passing on to the Start area, remarks by Dr. Hendriks should be noted on the coarse conglomerate, known as the Menaver conglomerate, now considered not older than Middle Devonian (1937, Table 1, facing p. 350). Hill (1912, p. 200) described this rock and remarked on the absence of serpentine and gabbro fragments. In the revised memoir a complete list of fragments was given and the possibility of the rock being a volcanic agglomerate was mentioned (1946, p. 152). Dr. Hendriks (loc. cit., p. 346) says that the absence of serpentine agrees with evidence in Gerrans Bay and that the conglomerate is older than the 4d limestone of the Pendower Beach Beds (loc. cit., p. 345). This conglomerate at Nare Head is only one mile from the hornblende-gneiss and serpentine at Porthallow, so it is hard to understand why there are no fragments of them in it, if the latter is younger. My work at Porthallow, however, made me conclude that the hornblende-gneiss and serpentine are intrusive into the Devonian rocks and that that is the reason why no fragments of them have been found so far in the conglomerate.

The Start Area

In 1938 two visits to the Lizard and two to Torcross enabled me to compare the Lizard with the Start area. The geology of the latter is

not so complex. To the south of the boundary is an anticlinorium of mica-schists pitching west with two bands of green schists derived from igneous rocks converging on the west coast. North of the boundary are Devonian rocks ; as mapped it is almost a straight line from west to east, unlike the complicated boundary line of the Lizard.

Two main questions have been discussed : are the mica- and green schists Devonian rocks more altered than those on the north of the boundary or older than Devonian ; and, what is the nature of the boundary, is it a fault, a thrust, both or neither ? The arguments were summarized by Ussher and Teall in the memoir (1904, pp. 42–5) and in Chapter V the nature of the boundary is discussed without any definite conclusion ; but earlier Ussher had written (1891, pp. 511 and 512) : " From these facts it seems evident that the chloritic series " (the green schists J.B.S.) " is nothing more than a Devonian volcanic group. The more evident crinkling of the mica-schists in contact with the chloritic group seems to be due to their comparative softness and greater fissility during the crumpling and contraction to which both were subjected. . . ." Somervail and Hunt thought the mica- and green schists were Devonian ; and Teall wrote (1904, p. 45) in support of Hunt's evidence (1891, 1892) : " It may perhaps be as well to state here that the work of the Survey has tended still further to emphasize this point " (petrological similarity J.B.S.) " . . . Whatever the age of the rocks in the metamorphic area may be, it is practically certain that they represent a series of arenaceous and argillaceous deposits with which a considerable amount of basic igneous material was associated, and that, as far as original composition is concerned, they can be matched by rocks occurring in the Devonian area though the igneous and sedimentary types do not occur in the same relative proportions."

Tilley, however, said (1923, p. 193) : " The boundary line represents a plane of major dislocation bringing together rocks of different origin and markedly different grades of metamorphism." Of Hunt he said (op. cit., p. 191) : " The views of Hunt with regard to analogies in mineral composition between Devonian rocks and members of the Start schists are scarcely cogent evidence for the correlation of these two groups of sediments." Nevertheless, similarities of a petrological and mineralogical nature are frequently used as a basis for correlation when palaeontological evidence is wanting.

In addition to field-work I was able through the courtesy of the Director of the Geological Survey to borrow a number of rock-sections for examination. Regarding this question of mineral similarity, Hunt (1891) made a point of tourmaline occurring in both series of rocks. No one questions that ; but tourmaline is so widespread and persistent a mineral that it cannot be regarded under ordinary circumstances as

a guide to comparative age. In this case, however, there is something to be said for Hunt, because tourmaline, apparently all of detrital origin, is commoner than usual in some specimens of both series of rocks. The following are notes on slides in the Survey collection :—

North of the Boundary.

3081. Grit, cliffs south of Strete (east coast). Tourmaline occurs and there is a good deal of muscovite.
3083. Grit, Beacon Point (west coast), north of Outer Hope. Quartz, muscovite, a little calcite, possibly epidote, and several grains of tourmaline.
3095. Same locality as 3083. Tourmaline common.
3120. Siliceous grit, Mayson, Beeson. Several grains of tourmaline.
3079. Gritty shale, Tinsey Head (east coast, near the boundary). Much tourmaline.
3124. Mica-schist, Tinsey Head. Though labelled mica-schist it is not a good example, but there is quite a lot of muscovite visible in the slide. A few grains of tourmaline.

South of the Boundary.

1780. Quartz-schist, Start Point. Much tourmaline. This slide is mentioned on p. 48 of the memoir.
3113. Mica-schist, Start Point. Tourmaline occurs.
3116. Mica-schist, south of Bickerton Valley. Tourmaline occurs.

Tilley (1923, p. 179) mentions tourmaline as an accessory mineral of the mica-schists, with titanite, iron-ores, epidote, zircon, rutile, apatite, and ilmenite.

On p. 48 of the memoir Hunt is quoted as saying, in connection with quartz-schists south of Start Farm : " . . . the quartz-schist bands containing tourmaline have much resemblance to the grit bands in the slates, both in relation to the mica-schists and in their fineness of grain. If there is no connection between the two sets of rocks, the conditions of sedimentation at the deposition of the schists must have been exactly repeated in Devonian times." The presence of titanite (sphene) as an accessory in the mica-schists is interesting. It is less stable than tourmaline, and if it could be proved to be present in the undoubted Devonian sedimentary rocks as well it would be better evidence for correlation than the tourmaline. I cannot find any mention of it. A systematic examination of the heavy minerals in both groups of rocks might give valuable information. At present Hunt's stress on the importance of the tourmaline is not so impressive as other evidence. My visits to Torcross enabled me to examine the coast-sections up to Start Point thoroughly, with the result that the mica-schists appeared to me to be the Devonian rocks subjected to a greater degree of dynamic metamorphism, and the rocks at Tinsey Head appeared to be a transitional type (see note on slide 3124 above).

On the west coast, at Mouthwell Beach, the dip of the slates is very steep to the north, but the mica-schists and green schists on the Inner Hope Beach dip south. In between is Hope Headland where the slates

have been badly disturbed, but a steep northerly dip can be seen. The mica- and green schists are obviously much sheared, as though thrust from the south. On Mouthwell Beach at low tide a strip of sand was seen running seaward between low walls of Devonian rocks. At the head of the beach weathered black slate and yellow rock were exposed. No fault-breccia was visible but it looked as though the sea had cut in along a weak band, possibly caused by a fault. On the north the Devonian rocks resemble those of Tinsey Head. On the south they are more like mica-schists and more disturbed. In the Inner Hope cliff-section, which is shown in the frontispiece of the memoir, I thought that the green schists resembled the sheared igneous rocks at Dun Point ("Limpet Rocks" on the 1 in. map), at Torcross. The latter are described in the memoir by Teall (1904, p. 28) as a probably modified diabase consisting of carbonates, chlorite, scales that are perhaps white mica, quartz, and felspar. That they are a northerly extension of the green schists associated with the mica-schists does not admit of much doubt. The green schists of Inner Hope are described by Teall in the memoir, on pp. 60 and 61.

Inland I was unfortunate in not being able to examine the Southpool Creek section closely, but Ussher gives a drawing of it (1904, p. 55, fig. 23). This shows Devonian slates separated from "Brown Rocks" and green schists by a thrust from the *north*, not south, described in the text as a thrust with a northerly inclination of 45°. Tilley (1923, pp. 191, 192) says of this section that it is one of the best for evidence of a dislocated junction, and that the junction is marked by an ironstone band hading northwards.

The boundary on the east coast is shown on the 1 in. map at Greenstraight. It is figured by Ussher (1904, p. 53, fig. 22) and again he shows a thrust from the north. The text shows that he was doubtful about this being the boundary. When I saw the section in 1908 it was so weathered that it did not afford much information. Tilley (1923, p. 177) said that he regarded the green schists mapped here as Devonian rocks, and that the actual junction seemed to be hidden in the valley. This valley makes the coast section, at the critical point, more unsatisfactory than that on the west. It does not help to elucidate the question of what the boundary is, a great thrust, or a fault and if so whether a normal or reversed fault, or is it a band along which there have been dislocations involving faults and thrusts? There does not seem to be any evidence for a great thrust in the sense of a force that caused the mica- and green schists to override the Devonian rocks; but the high north and south dips suggest lateral pressure resulting in folding, shearing, faults, and thrusts with dynamic metamorphism greatest on the south because that was the direction from which most pressure came. If the boundary is a single normal fault hading south

it would mean that more metamorphosed rocks had originally been above the Devonian beds ; if reversed, it would suggest that Devonian rocks in depth were more metamorphosed and had, along this line, been pushed up, which is understandable.

Tilley described the green schists as mainly chlorite-epidote-albite and hornblende-epidote-albite schists with a very small amount of quartz, all derived from igneous rocks. Nodular masses occur consisting mainly of epidote with chlorite, albite, hornblende, and, at Hamstone Cove, quartz (1923, p. 181). He wrote (op. cit., p. 200) : " The mica-schists of the Old Lizard Head Series bear comparison with the Start mica-schists, while the hornblende-schists considered by Dr. J. S. Flett as originally lavas and sills are chemically identical with the green schists." The hornblende-schists referred to are Flett's Landewednack type, called by E. H. Davison (1930) and myself, gneiss, not of metamorphic origin. The analysis given by Tilley of a specimen of Start green schist (op. cit., p. 183) is remarkably like that given by Flett of the Lizard rock (1912, p. 48), but the two rocks differ in mineral constitution and origin. On the other hand, the green schists in the Old Lizard Head Series are distinct from the Landewednack hornblende-schist (Scrivenor, 1938, p. 518) and resemble the Start green schists, but albite has not been proved so far and quartz is more abundant. Tilley (1937, p. 307) mentioned acid plagioclase in granulites at Pistil Ogo. It seems reasonable, without proof of close mineral resemblance, to regard the Lizard green schists as of the same age and origin as the Start green schists, i.e. derived from igneous rocks contemporaneous with and perhaps intrusive into the mica-schists of both areas.

The mica-schists of the Lizard differ from those of the Start in that they show evidence in the neighbourhood of Lizard Head of thermal metamorphism which has not yet been detected in the Start mica-schists. At Lizard Head this has been ascribed to the Man of War Gneiss (Flett, *supra*, 1946, p. 118) exposed in the islets off the coast. This leads to consideration of what we know about the bed of this part of the English Channel.

Hunt (1880–5, with notes by E. B. Tawney and T. G. Bonney) gave valuable information on this subject. The following rocks were recorded as having been collected in trawls : gabbro with killas attached ; actinolite rock ; diabase ; flints ; granite from a ledge twenty miles south-west of Eddystone ; gneiss and red granite of Eddystone. Hunt said that there is a large tract of the sea-bottom off the south coast of Devon where blocks of rock abound, and added that they could be roughly grouped into granites, gneisses, syenitic rocks, serpentine, diorite, diabase, gabbro, and conglomeratic grit (1881, p. 168). Tawney and Bonney described specimens in some

detail, including three from the Eddystone Rock. The granite-ledge is about twenty-five miles due south from a point on the coast of Cornwall four miles east of Fowey. Gabbro and actinolite rock were trawled about sixteen miles due south of Start Point. How far the rocks other than those from the ledge and from Eddystone can be regarded as *in situ* is not known ; but the information Hunt gave affords reason for believing that a considerable area of granite, gneiss, etc., exists on the sea-bottom in this part of the English Channel. The gneiss indicates pressure, so it may be that the crust here was subjected to a higher degree of disturbance than the crust farther north during Armorican movements, resulting in a higher grade of dynamic metamorphism seen in the Lizard and Start schists.

Summary

The Nature of the Boundary

Beginning in the west, the fault on Polurrian Beach was very clear in 1936 hading S.E. 45°, but later it was covered by a fall from the cliff. On the 1 in. map it is marked too far to the south as though cutting the Polurrian Hotel. Its real postion is consistent with being in the valley north of the hotel. If produced seaward it would pass north of Mullion Island with its pillow-lavas and radiolarian cherts, which is not consistent with its being a Lizard boundary-fault. Inland it has been mapped as ending in the Lizard group. On p. 206 of the 1912 memoir is the following : " Moreover, the very fact of its entering the Lizard group shows that it is only of local importance." In 1936 this was one of the clearest faults in the Lizard or the Start. In the former there are two other clear faults separating serpentine from older rocks, one on Pentreath Beach, near Lizard Town, where it hades N.N.E. ; the other at the Balk, hading N.W. In Housel Cove there is a clear fault hading N.E. 45°, and an equally clear thrust, hading N.W. 5° in hornblende-gneiss, that forms a platform in the cliffs.

At Porthallow shearing is very strong. The boundary fault as mapped goes off into the killas but I was unable to trace it inland. The geology of Porthallow was discussed thoroughly in my fifth paper (1938). Dr. Hendriks has published a clear section of the coast up to Nare Point (1937, pl. xxiii, fig. 3), but I cannot agree with her " Lizard Boundary crush belt (Great Thrust) " at Porthallow because killas occurs on either side of it and there are thrusts along the coast to the north that are no less great. They all hade southward. In the section from Loe Bar to Polurrian Cove all the dislocations except two are shown hading southward (loc. cit., fig. 4). Inland faults and thrusts forming a boundary are only conjectural though the sections on both coasts make one expect dislocations in the intervening country. This

absence of positive evidence applies to the rock-exposures at Gweleath, described in the revised memoir (1946, pp. 117, 118). The "Lizard Boundary" is really the northern limit of the large intrusions of hornblende-gneiss and serpentine.

For the Start area Ussher (1904, pp. 11, 12) gives a summary of schistosity-dips from Mouthwell, Salcombe, and Bickerton Valley (east coast) northwards. They are northerly, southerly, and vertical. I found that the prevalent dips on the east coast are northerly, even at Hallsands south of the boundary. At Start Point the prevalent dip is steep to the south. Unlike the country north of the Lizard there is no evidence here of a force causing shearing from the south only. There seems to have been a compression from the north and south and the supposed boundary between Devonian and older rocks is a line where the two forces met. There is no evidence of a great thrust from the south but the higher grade of metamorphism on the south is probably explained by the compression having been stronger from that direction. The brown rocks frequently mentioned in the memoir are the result of weathering of limestone lenticles, green schists, and perhaps sedimentary Devonian rocks also.

The Age of the Mica-schists

Unless recognizable organic remains are found, only very careful field-work can guide us to a solution of the question whether the mica-schists in both areas are Devonian or older. My field-work in 1936, 1937, and 1938 convinced me that they are Devonian (see 1938, pp. 101–5) as far as the Lizard is concerned. In the Start area the east-coast sections from Torcross to Start Point are to me equally convincing that there also the mica-schists are Devonian.

REFERENCES

DAVISON, E. H., 1930. *Handbook of Cornish Geology.*

FLETT, J. S., and HILL, J. B., 1912. Geology of the Lizard and Meneage. *Geol. Surv. Great Britain*, Explanatory Memoir of Sheet 359.

FLETT, J. S., 1946. Second edition of the above.

HENDRIKS, EILEEN M. LIND, 1937. Rock Succession and Structure in South Cornwall. *Quart. Journ. Geol. Soc.*, xciii, 322–367.

—— 1939. The Start-Dodman-Lizard Boundary Zone in relation to the Alpine Structure of Cornwall. *Geol. Mag.*, lxxvi, 385–402.

HUNT, A. R. Notes on the Submarine Geology of the English Channel off the coast of South Devon (with notes by E. B. TAWNEY), *Trans. Devon. Assoc.*, 1880, 291–301; 1881, 163, 172; 1883, 202–210; 1883, 353–367; 1885 (with notes by T. G. BONNEY), 292–7.

—— 1891. On the Occurrence of Detrital Tourmaline in Quartz-schist west of Start Point, South Devon. *Geol. Mag.*, xxviii, 465, 466.

—— 1892. On Certain Affinities between the Devonian Rocks of South Devon and the Metamorphic Schists. *Geol. Mag.*, xxix, 241–7, 290–4, 341–8.

SCRIVENOR, J. B., 1938*a*. Notes on the Geology of the Lizard Peninsula. No. 1. Some Mullion Rocks. *Geol. Mag.*, lxxv, 304–8.
—— 1938*b*. The Primary Hornblende-schists and Gneisses (the Lizard Hornblende-schists). Ibid., 385–394.
—— 1938*c*. The Epidote Bands, Lenticles, and Veins. Ibid., 515–526.
—— 1939*a*. " The Devil's Frying Pan," Cadgwith. *Geol. Mag.*, lxxvi, 37–41.
—— 1939*b*. Porthallow and Neighbourhood : Folding : Tourmaline-bearing Rocks. Ibid., 97–109.
STUBBLEFIELD, C. J., 1939. Some Devonian and supposed Ordovician Fossils from south-west Cornwall. *Bull. Geol. Surv. Great Britain*, No. 2, 63–70.
TEALL, J. J. H. See under USSHER, 1904.
TILLEY, C. E., 1923. The Petrology of the Metamorphosed Rocks of the Start Area (South Devon). *Quart. Journ. Geol. Soc.*, lxxix, 172–204.
—— 1937. Anthophyllite-Cordierite-Granulites of the Lizard. *Geol. Mag.*, lxxiv, 300–9.
—— 1938. The Status of Hornblende in Low-grade Metamorphic Zones of Green Schists. *Geol. Mag.*, lxxv, 497–511.
USSHER, W. A. E., 1891. Vulcanicity in Lower Devonian Rocks. The Prawle Problem. *Geol. Mag.*, xxviii, 511, 512.
—— with notes by J. J. H. TEALL, 1904. Geology of the Country around Kingsbridge and Salcombe. *Geol. Surv. Great Britain.* Explanatory Memoir of Sheets 355 and 356.

CORRESPONDENCE

PHOTOGRAPHIC PRINTS FROM CELLULOSE-ACETATE TRANSPARENCIES

SIR,—The method of obtaining cellulose-acetate transparent moulds from etched surfaces has been previously described in detail (Walton, 1928 ; Leclercq, 1928) and is now a recognized palaeontological technique. In the case of corals or other organisms with calcium carbonate skeletons, the method does not replace the thin section, but it is a valuable substitute for it because of its speed and ease of preparation, the lack of any risk that the section will be lost in the last stages of preparation, and as a permanent record of serial sections which are progressively destroyed as they are made. One of the disadvantages of the " cellulose pull " is its lack of contrast and the difficulty of translation of its detail to a photographic print. Various techniques to overcome this have been described (Walton, 1928 ; Dollar, 1948), but I have not read of one which does not depend on pigment or staining to obtain the necessary contrast.

Working recently with cellulose transparencies of Carboniferous corals, I was able to produce direct enlargement prints from the " pulls " with strong contrast almost equal to that obtainable from a thin section. The process involved nothing more than an adaptable enlarger and the correct selection of paper, developer, and fixer. In view of the widespread use of cellulose pulls, it was suggested that the details of procedure might be published.

The use of grade IV gaslight paper in conjunction with an enlarger will normally be found to supply the desired contrast. The great disadvantage of gaslight paper used in this way is the length of time of the exposure, but a photoflood bulb in the enlarger will overcome this. The distance of the bulb from the condenser in the enlarger may have to be varied in order to obtain even illumination. Conveniently there are two normal sizes of photoflood bulbs—No. 1 with bayonet fitting, about the size of a 60 watt bulb and No. 2 with Edison screw fitting about the size of a 150 watt bulb. The length of time of exposure naturally will vary considerably depending

on which type of bulb is used and the peculiarities of each enlarger. Using a No. 2 photoflood and a lens aperture of f12, I find an average exposure to be in the region of ten seconds for an enlargement of 2 diameters. So far as possible ground glass plates in any position in the optical system of the enlarger should be dispensed with. They disperse the light and reduce the contrast.

Experiment has proved both Kodak and Ilford gaslight papers grade IV to be equally suitable. The Kodak paper, if anything, is a shade more contrasty. Glazing, if convenient, is well worth while. For development Kodak Special Developer D. 163 has given the best results, and if diluted 1 to 1 instead of 1 to 3 and used warm (100° F. or 38° C.) gives more contrast than many of the special contrast developers. The print " comes up " very quickly because of the temperature of the developer, but exposure can be regulated to give a two-minute development time. Fixing in double strength acid fixer clears the print still further due to the slight reducing effect of the hypo.

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11th October, 1949.

REFERENCES

DOLLAR, A. T. J. *Nature*, March, 1948, vol. 161, 358.
LECLERCQ, S. *Ann. Soc. géol. de Belgique*, 1928, vol. 52.
WALTON, J. *Nature*, 1928, vol. 122, 571.

BOREHOLE SECTIONS AT ROSENEATH AND ROW

SIR,—In his recent paper on " The Gareloch Re-Advance Moraine " (*Geol. Mag.*, lxxxv, 239–244), Dr. J. G. C. Anderson has discussed the interesting section of raised beach and moraine deposits seen in the cliff along the north-western side of Row Point, and has remarked on the absence of any similar evidence with regard to the internal structure of Roseneath Point. Some war-time borings, which provided sections on both sides of the loch entrance to 60–70 feet deeper than the base of the Row Point exposures, may now be placed on record.

During the construction of a military port, the Consulting Engineers to the scheme maintained the possibility, despite geological arguments to the contrary, that the Row and Roseneath spits might be based, at no great depth, on a solid rock bar ; in which case a considerable amount of blasting might be necessary to clear a channel adequate for vessels of 30 feet draught at all states of the tide. A detachment of 7 Boring Section, R.E., put down three holes, in July, 1941, to decide the matter. The holes were restricted to testing to a depth of 30 feet below low water mark, and all of them failed to reach solid rock within this limit.

The first hole was sited at high water mark on the outermost point of the Roseneath spit. After casing-off 8 feet of loose shingle the hole passed through 52 feet of thinly-bedded blue-grey clays and silts to its finishing depth of 60 feet. The second hole also was drilled from high water mark on the Roseneath spit, but to the south of the pier, and at about the same distance from it as No. 1. The section proved was practically identical with that of No. 1 : shingle, 8 feet ; blue-grey clays and silts, 53 feet. The third hole was drilled from a barge, which was grounded after manoeuvring into position at high tide, about ten yards south-east of the navigation beacon at the outer end of the Row spit. The section in this hole was : shingle, 26 feet ; soft blue-grey clays and silts 30 feet.

A channel to 30 feet below Chart Datum over a width of 400 feet was dredged subsequently at Row Point without encountering any solid rock. A large portion of the 150,000 cubic yards removed was " ballast ", and was used for filling-in behind the 150-ton floating crane berth at Faslane Bay.

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REVIEWS

LANDSCAPE AS DEVELOPED BY THE PROCESSES OF NORMAL EROSION. By C. A. COTTON. 2nd edition, pp. 507, with 375 figures. Whitcombe and Tombs, Ltd., Christchurch, New Zealand. 1948.

The first edition of this book was published by the Cambridge University Press in 1941. This second edition has been a good deal enlarged and in part rewritten. A good many photographs have also been added and the whole has been printed and produced in New Zealand. Meanwhile, Professor Cotton has written three other books : *Geomorphology*, an introduction to the study of land forms ; *Climatic Accidents in Landscape Making*, about arid regions and glaciation ; *Volcanoes as Landscape Forms*, a title which explains itself. The last two and the present book form a trilogy, which covers the whole subject of landscape making so far as now developed. The one section of the subject which has not yet been worked out in detail is landscape in wet tropical climates, except by Sapper, in German, and by the American geologists in Hawaii.

Naturally the examples are chosen and most of the photographs are taken from New Zealand, which affords very fine specimens of nearly all the types of scenery attributed to what is generally known as normal landscape making —that is the action of water and rivers. As a matter of fact this is not really more normal than anything else, such as glaciation, aridity, and volcanoes, but it is much commoner, although it should be remembered that it is estimated that about one-fifth of the whole land surface of the earth is arid, much of it absolute desert and therefore not much seen.

The work of W. M. Davis is very largely quoted, and a great number of his diagrams are reproduced, either directly or redrawn. Occasionally in these the perspective has not quite come off, especially in meanders, and in a few instances one wonders whether Davis really saw anything like that or whether he invented the whole thing. The general impression given by most of the photographs in this as well as the other books, is that the scenery of New Zealand is very exaggerated, and most remarkably varied.

While it is perhaps permissible to express a little scepticism as to some of the Davisian diagrams, Professor Cotton is to be heartily congratulated on the general success of the book, which is about the best non-American work on the subject. It is eminently readable, and is suited both to the general reader and to the specialist.

R. H. R.

THE GEOLOGY OF WATER SUPPLY. By SIR CYRIL S. FOX. pp. x and 209, with 49 figures and xxiii photographs. The Technical Press, Ltd., 1949. Price 25*s*.

Sir Cyril Fox has a life's experience of the practical application of geology to everyday problems. This book is written to give some of that experience to others but, as he says in the Foreword : " books . . . cannot by mere reading, provide that information gained by actual experience." Throughout, the text points are illustrated from Sir Cyril's own experience or by quotations from that of others. Naturally, many of the examples are drawn from India.

Throughout, the book contains much in the way of tabulated facts and figures which it will be useful to have collected together in one book, but at times it is rather hard to see why some of them are included in a book on the geology of water supply. For instance, on page 51, under " Thermometer ", we have a selection of temperatures from that of the electric arc to absolute zero, and on page 206 there is a list of chemicals with their " common names " and chemical names and formulae.

The text is illustrated throughout by accounts of floods, storms, engineering enterprises, etc., but again, some appear to be hardly relevant, as for instance the story of the recovery of the *Laurentic's* gold by divers—given verbatim from the *Daily Mail's* account of the proceedings.

Since so much has been published in the official memoirs and in books on water supply in the United States, it is strange to find practically no references to these works, and it may also be noted that very few of the papers quoted in the text date from the last twenty-five years.

There are some good photographs but the diagrams are, on the whole, poor.

W. B. R. K.

THE MIDDLE SILURIAN ROCKS OF NORTH WALES. By P. G. H. BOSWELL. pp. xvi + 448, with 25 plates and numerous text-figures. Edward Arnold and Co., 1949. Price 80*s*.

This book is the record of the vast amount of work which Professor Boswell has done on the Lower Palaeozoic rocks of the Denbighshire moors. As he says, he has been working in this area for over twenty-five years and naturally during that time has accumulated a wealth of detail and large collections of fossils.

The book is divided into two main but unequal parts: Pages 1–175 (Part I) deals with the general geological problems of the area as a whole, and in this geologists will find much of value and general application. After a general introduction, there is a chapter on Stratigraphy, in which there is an account of the general characteristics of the lithology and palaeontology of the successive zones with details of thicknesses, lithology, etc., in the various areas, and fairly full lists of fossils. In fact, these 35 pages give an admirable and full summary of the 258 pages of Part II. Details of structure follow with critical studies of fault and joint patterns, and of the cleavage fan which is claimed to be present. A map indicating the extremely irregular distribution of cleavage strength shows how complex the cleavage problem is in this district. The presence of a " cleavage sanctuary " near the Carboniferous boundary tends to lessen the value of the implications drawn from the presence of uncleaved Silurian rocks in the Carboniferous conglomerates. The next pages deal with the interesting subject of Intraformational Disturbances—a subject which has given rise to considerable controversy. Professor Boswell discusses the characteristics of these beds, their condition at the time of disturbance, and the views which have been put forward to explain these and similar disturbed beds from other areas. As a result, Professor Boswell considers that disturbed beds may arise from various causes of which submarine sliding or slumping is but one. He tends to minimize the importance of these beds in the general succession. However, from this book it would appear that the matter in dispute is now more one of degree than anything else.

The first part of the book ends with chapters on the petrology and palaeontology. These bring out the monotonous character of the series, and appear to justify the mnemonic that the graptolite zones of the Ludlow contain " merely last traces, some nasty varieties ", a saying which even if not quite true does help one to remember the order in which the zones occur.

For these 175 pages all geologists will be grateful, but Part II runs from pages 176 to 434, and is headed " Details of the Areas ". Maps illustrate each area, but many are reprints of maps previously published in various

scientific journals. The minutely descriptive accounts may be of value to workers going into the area and anxious to find the best fossil localities and exposures. In these days when there is such difficulty in getting new work published even on a much reduced scale, one wonders if all this detail is justifiable.

W. B. R. K.

FEDERATION OF MALAYA : REPORT OF THE GEOLOGICAL SURVEY DEPARTMENT FOR THE YEAR 1948. By F. T. INGHAM, Director. pp. 59, with 2 maps and a Folding Chart. Government Press, Kuala Lumpur. 1949. Price $2 or 4*s*. 8*d*.

The work of the Geological Survey seems to have been more or less normal in 1948. One or two bits of field work are unfinished owing to bandit activity, and some of the time of the staff was taken up with organizing Special Constabulary. The work of the Chemical Department went on as usual, with two chemists for part of the year.

The principal items of work carried out were as follows : In West Central Pahang, by H. E. F. Savage ; near Kuala Lipis, by H. Service ; near Bentong, Pahang, by J. B. Alexander ; in North Selangor and Ulu Selangor, by F. W. Roe ; near Kuantan, Pahang, by F. H. Fitch ; in Southern Trengganu, by A. C. Amies. The Director accompanied Dr. F. Dixey to Borneo, Sarawak, etc. Some more fossils have been collected and identified in England. They are mostly Carboniferous.

R. H. R.

STRUCTURAL HISTORY OF THE EAST INDIES. By J. H. F. UMBGROVE. 63 pp., 68 text-figs., x plates. Crown quarto. Cambridge University Press. 1949. Price 30*s*.

Many who heard Professor Umbgrove deliver his six lectures in Cambridge in 1946 will be glad to learn that the substance of these is now published. In the preface it is clearly stated that little has been done to modify the original form of the contribution. The author therefore cannot be blamed for the disappointment which many will feel on realizing that the fine appearance of this book, with its comprehensive title, generous illustrations, and large page size, does not reveal a new and authoritative treatise on so important an area.

The six chapters are entitled The Shallow Seas, Deep-sea Basins and Troughs, Volcanoes, Structural Zones, Geophysics, and Synthesis. Throughout interest is not narrowly confined to structural history, and a discussion for instance on the distribution of Red Clay and Globigerina Ooze in modern deposits is thrown in for good measure. Geologists will find the main meat in Chapter IV, Structural Zones, in which the salient facts concerning Palaeozoic and Mesozoic history are outlined. With more evidence in the Tertiary four structural zones are distinguished by different stratigraphical histories.

As a series of lectures they are admirable, being easy to follow without the encumberance of detail which is shown diagrammatically. Professor Umbgrove has drawn on a rich source maps and diagrams in the prolific publications of this Dutch School. The spoken style with its ready admixture of fact and opinion, argument and prejudice, makes for rapid and stimulating reading. There is no encouragement, however, to think more deeply into the many interesting problems, as neither data nor references are adequately provided. One is therefore left with a feeling of remoteness from field geology which inevitably derives from summaries of summaries.

This is a valuable book outlining Professor Umbgrove's opinions from a host of publications, but an opportunity has been lost of publishing a study of more permanent value when such a fine production was materially possible.

W. B. H.

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